This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

DOC.
D 207.208/2:2
G95/9

Naval Education and Training Command

NAVEDTRA 10292
May 1990
0502-LP-212-3800

Training Manual (TRAMAN)

DEPOSITORY
AUG 31 1990
UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Gunner's Mate (Guns) First Class

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-3800

The terms training manual (TRAMAN) and nonresident training course (NRTC) are now the terms used to describe Navy nonresident training program materials. Specifically, a TRAMAN includes a rate training manual (RTM), officer text (OT), single subject training manual (SSTM), or modular single or multiple subject training manual (MODULE); and an NRTC includes nonresident career course (NRCC), officer correspondence course (OCC), enlisted correspondence course (ECC), or combination thereof.

UNIVERSITY OF
ILLINOIS LIBRARY
AT URBANA-CHAMPAIGN
BOOKSTACKS

Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading this text.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must write to Superintendent of Documents, Government Printing Office, Washington, DC 20402 OR Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, Attention: Cash Sales, for price and availability.

Naval Education And Training Program Management Support Activity

GUNNER'S MATE (GUNS) FIRST CLASS

NAVEDTRA 10292

DEPARTMENT OF THE NAVY ★ CHIEF OF NAVAL EDUC AND TNG

1990 Edition Prepared by
GMCS(SW) Ricardo M. Andres, Jr.

PREFACE

This training manual (TRAMAN), Gunner's Mate (Guns) First Class, NAVEDTRA 10292, is intended to provide personnel of the regular Navy and Naval Reserve with background information useful in preparing for advancement to the rate of GMG1. This includes information on synchros, power drives, fire control, battery alignment, test equipment, fuze setting devices, administration, and maintenance.

Designed for individual study rather than for classroom instruction, this TRAMAN provides subject matter that relates directly to the occupational standards for GMG1. A separate nonresident training course (NRTC), NAVEDTRA 80292, provides the usual way of satisfying the requirements for completing the TRAMAN. It consists of a set of assignments that includes learning objectives and supporting questions designed to lead the student through the TRAMAN. You may find it beneficial to browse the entire training package and to read the front matter to the NRTC before you begin serious study.

This TRAMAN was prepared by the Naval Education and Training Program Management Support Activity, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Gunner's Mate School, Service School Command, Great Lakes, Illinois; Mobile Technical Unit (MOTU) 12, Mayport, Florida; Commander, Naval Ordnance Station, Louisville, Kentucky; Commander, Naval Sea Systems Command, Washington, D.C.; and the FMC Corporation, Minneapolis/St. Paul, Minnesota. Their reviews, comments, ideas, and suggestions have been most helpful.

1990 Edition

Stock Ordering No.
0502-LP-212-3800

Published by
NAVAL EDUCATION AND TRAINING PROGRAM
MANAGEMENT SUPPORT ACTIVITY

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON, D.C.: 1990

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER Page

1. The Gunner's Mate G (GUNS) Rating 1-1
2. Synchros and Servo Systems 2-1
3. Amplidyne Power Drives 3-1
4. Amplidyne Control Equipment 4-1
5. Hydraulic Power Drives 5-1
6. Hydraulic Control Equipment 6-1
7. Fire Control 7-1
8. Battery Alignment 8-1
9. Test Equipment 9-1
10. Fuze-Setting Devices 10-1
11. Ammunition Handling and Stowage 11-1
12. Administrative Duties 12-1
13. Maintenance 13-1

INDEX INDEX-1

CHAPTER 1

THE GUNNER'S MATE G (GUNS) RATING

We have prepared this training manual (TRAMAN) for personnel of the regular Navy and the Naval Reserve. We have organized it to give you a broader understanding of your job as a Gunner's Mate Guns (GMG), and to expand your knowledge of the equipment and operating procedures for the various gun systems.

This TRAMAN provides information based on the occupational standards for advancement to GMG1. These standards are promulgated in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068-E. Changes in the GMG standards occur periodically. It is important that you obtain and study a set of the most recent standards.

The associated nonresident training course (NRTC), formerly called an enlisted correspondence course, is published under a separate cover, NAVEDTRA 80292. It is a self-study enlisted training course that includes a comprehensive series of questions based on the material in this TRAMAN, and is designed to assist you in studying for advancement. It must be satisfactorily completed before you can participate in the Navywide advancement examination for GMG1.

SENIOR PETTY OFFICER RESPONSIBILITIES

With each advancement, you will accept an increasing responsibility in military matters and in matters relating to the occupational requirements of the Gunner's Mate rating. In large measure, the extent of your contribution to the Navy depends upon your willingness and ability to accept these responsibilities.

Your responsibilities for military leadership are similar to those of petty officers in other ratings; your responsibilities for technical leadership are directly related to your work as a GMG. The effective operation and maintenance of a ship's gun system requires a leader who has a high degree of technical competence and a deep sense of personal responsibility. As a senior GMG, you must strive to improve your leadership ability and technical knowledge through study, observation, and practical application.

EFFECTIVE COMMUNICATION

Every phase of your duties as a leading GMG involves the use of language, spoken or written. You are expected to translate general orders given by officers into specific orders that can be understood and executed by relatively inexperienced personnel. At the same time, you must be able to explain to officers the important needs or problems of enlisted personnel. An understanding of the language of your rating will enable you to say exactly what you mean in the appropriate terms.

Effective communication demands the precise use of technical terms. A command of the technical language of the Gunner's Mate G rating will enable you to receive and convey information accurately and to exchange ideas with others. If you cannot understand the exact meanings of technical terms, you will be operating with a handicap when you try to read work-related official publications. You will also be at a disadvantage when you take a written examination for advancement in rating.

Particularly when training lower rated personnel, it is important that you use correct terminology. The importance of learning and using technical terms cannot be over emphasized.

STAY UP TO DATE

Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change as new developments come on line. Some changes will be pointed out to you; others you must find independently. As a GMG1, you will be required to keep informed of all changes and new developments which might affect your rating or your work.

Try to develop a special alertness for new information and keep up to date on all available sources of technical information. Above all, keep an open mind on the subject of gun systems and associated equipment. New types of guns are being designed and tested constantly, and existing gun systems are always subject to modification. A number of important changes in gun mounts have occurred and will continue to occur.

TRAINING

As a GMG1 you will have regular and continuing responsibilities for training others. Even if you are fortunate enough to have highly skilled and well-trained Gunner's Mates working for you, you will find that continuous training is still necessary. You will always be responsible for training lower rated personnel for advancement. Some of your personnel may be transferred, and inexperienced or poorly trained personnel may be assigned to replace them; or a particular job may call for skills that none of your personnel have. Such circumstances require you to plan and conduct formal and informal training

At times this training will affect a large number of personnel not in your division or even in your department. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. The more you know about related ratings, the more complete and comprehensive will be your training plans—especially those requiring an interdivisional effort to achieve their goals. As you know, the GMG must work very closely with the GMM to meet overall objectives. Greater sophistication in gun mount controls, for example, has required greater cooperation between the GM and FC ratings. Other ratings that are, at least in part, related to the Gunner's Mate G rating are the Sonar Technician (ST) and the Data Systems Technician (DS).

On-the-Job Training

Most readers of this TRAMAN will be concerned with on-the-job training. A number of instructional methods, ranging from the lecture to the demonstration-doing method, to the planned or impromptu discussion can be adapted to shipboard conditions.

Because there never seems to be enough time for training, odd moments between drills, at quarters while entering and leaving port, in the mess line, and so on, can be used to good advantage. Personnel should be encouraged to conduct training bull sessions where they ask each other questions about their work, Navy and ship orientation matters, examinations taken, and other training matters. On-watch time in the gun batteries during condition III watches is a good time for the gun captain to conduct equipment operation training of watch personnel.

New Training Techniques

Navy training is changing in several ways; for example, it is becoming more individualized. This change has been brought about by the introduction of scores of programmed instruction and audiovisual courses. These self-paced courses permit the trainee to choose the medium of instruction and to proceed at his or her own speed. The new instructional material is job related and system designed; that is, it teaches the trainee to perform a task, following specific steps which include defining the need, and planning, developing, and evaluating the course. Thus, all elements required for a complete course are included in each unit.

In the future, training for men and women in many ratings will be planned from the time they enter the Navy until they retire. Since the length of many, if not all, A schools will be reduced and others eliminated, more training will be done aboard the ship or station. To expedite this training, on-board training packages, many of them multimedia, will be produced. The objective is to provide all the training needed while eliminating irrelevant training.

Personnel Qualification Standards Program

The personnel qualification standards (PQS) program is a method for qualifying officer and enlisted personnel to perform specific duties. A personnel qualification standard is a written compilation, derived from task analyses, of knowledges and skills required to qualify for a specific watch station, maintain a specific equipment or system, or perform as a team member within the assigned unit.

Watch station, as it applies to PQS, refers to a position that normally is assigned by a watch bill, is usually of 4 hours duration and, in the majority of cases, is operator oriented.

To maintain means to perform tasks which pertain to technical upkeep of equipment and systems. **Performance as a team member within the unit** refers to the use of the knowledges and skills appropriate for standardized qualification that are not peculiar to a specific watch station or equipment, but apply more broadly within the unit.

More detailed information on PQS material that has been developed for the GMG is found in *Shipboard Training,* OPNAVINST 3500.32, and *Personnel Qualification Standards (PQS) Program*, OPNAVINST 3500.34C.

The senior GMG is responsible for the efficient functioning of the PQS program. The senior GMG will conscientiously sign off those qualifications of deserving personnel, monitor individual progress, and conduct the necessary training to ensure that personnel qualify in the time allotted.

Q1. What is the name of the program used to train personnel to perform the duties of a specific task or watch station?

THE GUNNER'S MATE RATING

As weaponry changes in types and complexity, so does the Gunner's Mate rating. When guided missile systems were added to the fire power of the fleet, selected personnel of the general rating of Gunner's Mate were given the responsibility for operating and maintaining the missile launching systems. As missile systems multiplied and became more sophisticated and the working knowledge of electricity and electronics became more extensive, the decision was made to separate the general service rating into three allied ratings. In 1961 the GM rating was split into three groups: the GMG (Guns); the GMT (Nuclear); and the GMM (Missile).

Effective 1 January 1987, the GMT service rating was merged with the GMM service rating through paygrade E-6. Both the GMG and GMM service ratings were converged at the E-7 level, forming a single GM rating. Each group is now responsible for maintaining, operating, training, and repairing the equipment of specific types of weapons systems.

The Gunner's Mate G is required to operate, inspect, and perform organizational and intermediate maintenance on conventional weapon groups and special handling equipment. He is also required to make detailed casualty analyses; inspect and repair electric, electronic, hydraulic, pneumatic, and mechanical systems and servo systems in gun mount systems. He must also supervise personnel in the handling and stowage of ammunition and the maintenance of magazine sprinkler systems. To obtain all the skills and technical background necessary for the maintenance, operation, and repair of gun mounts, the GMG must have an extensive knowledge of hydraulics. He must also be able to use a wide variety of tools and test equipment, and have a working knowledge of electricity and electronics as well as all explosives associated with conventional ordnance.

The GMG rating can be further subdivided into classes; each class is assigned a code number. The purpose of these codes is to assist in identifying personnel in a rating when a broad definition (such as GMG) is not sufficient to identify a special skill. These are called Navy Enlisted Classification (NEC) codes. The codes are changed to suit the needs of the Navy. At the present time, all trainees are given NEC code numbers. Occasionally, it becomes necessary to cancel certain codes; personnel in them are then recoded. A complete list of the codes is in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (latest revision).

CLASSIFICATION CODES

The Navy enlisted classification (NEC) structure supplements the enlisted rating structure in identifying personnel on active duty and billets in manpower authorizations. These classifications reflect special knowledges and skills that identify personnel and requirements when the rating structure is insufficient by itself for manpower management purposes. There are three types of NECs: Entry Series, Rating Series, and Special Series. Each will be discussed in turn.

Entry Series

Entry series NECs identify aptitudes and qualifications not discernible from rates alone. They are used to code personnel who are not yet identified as strikers or who are in training for change of rating or status. Rating conversion NECs parallel rating entry NECs but are assigned only to identify petty officers or identified strikers who are assigned in-service training for change of rating or status under approved programs. The rating conversion NEC for the GM rating is GM-0899 Gunner's Mate Basic.

Rating Series

Rating series NECs are related to specific source ratings. They are used to identify billet requirements that are not sufficiently identified by rates, and to identify the personnel who are qualified to be detailed to fill these requirements.

Special Series

Special series NECs are not related to any particular rating. They are used to identify billet requirements which are not sufficiently identified by rates, and to identify the personnel who are qualified to be distributed and detailed to fill these requirements. Special series NECs may be assigned to personnel in any rating, provided they are otherwise eligible to receive the training involved. It is not practical to present all of the special series NECs in this training manual.

ASSIGNMENT PRIORITIES

To facilitate central control of NEC assignments by allowing computer programmed instructions to position NECs as primary, secondary, and lower positions, a sequence code number is assigned to each NEC. These sequence code numbers (formerly called priority numbers) range from 1 to 8 and only one such sequence code number is assigned to an NEC.

Entry series NECs are assigned sequence code number 1. All other NECs are assigned a sequence code number of 2 through 8. The lowest sequence code number has the highest priority in sequencing NECs; e.g., sequence 2 takes precedence over sequence 3. In those cases where an individual earns two or more NECs with the same sequence code number, the NEC code that the individual most recently qualified for will take precedence, except in unusual circumstances; e.g., cost of training and length of course earning the NEC.

If a Gunner's Mate is qualified for an Ordnance System Technician (GM-0876-NEC), a 5″/54 mount Mk 42 Mod 9/10, and a 5″/54 mount Mk 45 Mod 0 (GM-0877 NEC), the Gunner's Mate will be coded GM-0876/GM-0877. The primary NEC is priority 4 and the secondary NEC is priority 3. The fact that one NEC is priority 4 and another is priority 3 does not imply that the priority 4 skill is a higher level skill than the priority 3 skill. Priority numbers are based on the need to retain NEC identification in any given instance, and this need varies for each rating.

The following is a partial list of the rating series NECs for the GMG rating, showing sequence codes, NECs, a brief description of the job involved, and source ratings.

Sequence Code	NEC	Job Description	Source Ratings
8	GM-0812	Small Arms Marksmanship Instructor. Performs specialized duties as small arms marksmanship instructor. Conducts training	GM, GMG, GMM, AO, TM

ANSWER TO QUESTION Q1.

A1. Personnel Qualification Standards (PQS) Program.

Sequence Code	NEC	Job Description	Source Ratings
		in all phases of basic marksmanship including firearms safety, mechanical training on small arms, qualification firing, hunter safety, range operations, coaching techniques, and records and reports. Performs preventive maintenance on weapons. Organizes and conducts small arms competitions.	
6	GM-0871	3″/50 Rapid-fire Mount (Single or Twin) Maintenanceman. Operates and maintains 3″/50 rapid-fire mounts and power drives. Performs organizational level maintenance. NOTE: NEC assigned after 2 years OJT.	GMG, GMM
6	GM-0872	5″/38 Dual-Purpose Mount (Single or Twin) Maintenanceman. Operates and maintains 5″/38 dual-purpose single or twin mount and power drives receiver-regulators. Performs organizational level maintenance. NOTE: Commanding officers are responsible for removal of this NEC should on-the-job performance so dictate following a minimum of 12 months onboard familiarization period.	GMG, GMM
4	GM-0875	16″/50 Turret Maintenanceman. Operates and maintains the 16″/50 caliber three-gun turret, including all electrical, hydraulic, mechanical equipment and systems comprising the turret and its magazines. Performs powder and projectile stowage and handling on board BB61-class ships. NOTE: Commanding officers are responsible for removal of this NEC should on-the-job performance so dictate following a minimum of 12 months on board familiarization period.	GMG, GMM
4	GM-0876	5″/54 Mount Mk 42 Mod 9/10 Maintenanceman. Operates and maintains the 5″/54 Mk 42 Mod 9 gun mount. Performs organizational level maintenance.	GMG, GMM

Sequence Code	NEC	Job Description	Source Ratings
3	GM-0877	5″/54 Mount Mk 45 Mod 0 Maintenanceman. Operates and maintains the 5″/54 Mk 45 Mod 0 gun mount. Performs organizational level maintenance.	GMG, GMM
3	GM-0878	Oto Melara 76 MM/62 Caliber Mk 75 Mods 0/1 Maintenanceman. Operates and maintains the 76 MM/62 caliber gun mount.	GMG, GMM
3	GM-0879	5″/54 Caliber Gun System Mk 45 Mod 1 Maintenanceman. Operates and maintains the 5″/54 caliber Mk 45 Mod 1 gun mount. Uses general- and special-purpose electronic test equipment to perform organizational level maintenance.	GMG

Q2. The special knowledges and skills of job enlisted classification codes (NECs) are for what primary purpose?

Q3. What are the three series categories of NECs?

GMG DUTY ASSIGNMENTS

All ships having conventional armament, or ammunition supply ships carrying ordnance, and shore activities where ordnance is repaired, assembled, tested, and/or stored, will have a GMG assigned for duty. A GMG's duties naturally will vary according to the NEC and the type of ship in which a gun system is installed. Some large ships may carry more than one gun system and require a large number of GMGs; smaller ships require fewer personnel. Since the number of GMGs varies according to ship type, so does the rate level of each ship. The senior GM aboard a large ship could be an E-8 or E-9; on a small ship the senior GM could be an E-6 or E-7. As a senior Gunner's Mate, your enlisted job code number is the primary factor in determining your assignability.

In training assignments ashore, GMGs serve as instructors in the Gunner's Mate School at Great Lakes, Ill.; as instructors in the Fleet Training Center, San Diego, Calif.; and as instructors in the Fleet Training Center at Dam Neck, Virginia Beach, Va. GMGs are also assigned to duty at the Naval Education and Training Program Management Support Activity (NETPMSA), Pensacola, Fla., as subject matter experts/writers for fleetwide examinations, training manuals, and nonresident training courses. In fulfilling duties in training billets, the knowledge gained afloat will be put to use in preparing training material. Personnel selected for training billets are carefully chosen and are expected to be experts in specific gun systems.

In addition to training billets, the GMG may be assigned duty ashore at naval ammunition depots where ammunition is stored and readied for issue to the fleet.

The billets mentioned above comprise a portion of the billets ashore for GMGs. In some instances primary duties will be military rather than technical or occupational; although such assignments are seldom made for personnel in critical ratings.

Out-of-Rating Assignments

Unfortunately, there are just not enough shore billets written for the GMG to allow shore assignments to those billets alone. Therefore, GMGs (as well as personnel in many other ratings) may be assigned to billets out of their rating

(Shore Patrol, Armed Forces Police, MAA, career counseling, drug abuse specialists, recruiting, courier, security groups, etc.) to alleviate this situation. Without these out-of-rating billets, shore duty opportunity for GMGs would be considerably reduced. Keep this in mind if you receive orders ashore which are not quite what you desired—chances are you were assigned close to the area of your choice.

Tour Lengths

The tour lengths for GMGs are determined by analysis of the distribution of billets between sea and shore duty, retention rate, and related manning level projections. As billet structures and activity allowances change, so do tour lengths. For this reason, specific tour lengths cannot be discussed in this manual. However, you can determine the tour lengths for your rate by contacting your personnel office or by calling your detailer.

PERSONNEL ASSIGNMENT SYSTEM

The basic concept of centralized assignment is simple. It provides the capability of matching total enlisted personnel resources against total requirements. Under this method, all enlisted members (with the exception of nondesignated SN/FN/AN) are under the exclusive detailing control of the Director of Military Personnel Command (NMPC), (formerly CHNAVPERS), who determines the member's ultimate assignment. Nondesignated SN/FN/AN are detailed by the Enlisted Personnel Management Center (EPMAC) in New Orleans.

PERSONNEL REQUISITION SYSTEM

The Personnel Requisition System was developed to enable NMPC to determine personnel requirements for activities Navywide. The requisition is prepared by the manning control authorities (MCAs) and lists the consolidated personnel requirements for each of their areas of cognizance.

Each requirement (by rate, rating, and NEC, if appropriate) is identified by a requisition number which must appear on orders issued to satisfy that requirement. The requirements are assigned priorities by the MCAs who consider such factors as command employment (deployment, CNO SPEC OPS, etc.) one-for-one billets, and onboard population in a given unit (i.e., 3 GMGs on board; 8 GMGs allowed).

Although the requirements are projected for up to 8 months, the requisition is updated monthly by the MCA in response to each command's Enlisted Distribution Verification Report (EDVR), Form 1080. Through the 1080, an individual requirement may be generated in the requisition for any of the following reasons:

1. To fill an existing vacancy
2. To relieve an individual on board
3. To fill a new billet

These new requirements are assigned appropriate priorities and are integrated into the requisition by the MCAs. Detailers are required to make assignments in strict accordance with requisition priorities.

TYPES OF DUTY

For rotation purposes, eight types of duty currently exist.

Type 1—Shore Duty: CONUS, fleet shore duty, and certain fleet activities.

Type 2—Sea Duty: Arduous sea duty in deploying ships/units homeported in CONUS, Hawaii, or Alaska.

Type 3—Overseas Shore Duty: Duty ashore outside CONUS where prescribed DOD tours are 36 months or less. Counts as sea duty for rotation purposes, but may not completely fulfill an individual's sea tour.

Type 4—Non-rotated Sea Duty: Sea duty in ships/staffs/units listed in OPNAVINST 4600.16 (for example, units homeported in Japan). Tour lengths are defined by the area tour for the locale of assignment. Counts as sea duty for rotation purposes, but may not completely fulfill an individual's total sea tour obligation.

Type 5—Neutral Duty: Duty in CONUS, Hawaii, or Alaska homeported ships/staffs/units that normally do not operate away from homeport, except for brief periods. Not credited for either sea or shore rotation. Sea duty commencement date (SDCD) or shore duty commencement date (SHDCD) is adjusted to compensate for the neutral time. You should expect another sea assignment upon completion of neutral duty.

Type 6—Preferred Overseas Shore Duty: Duty overseas where the prescribed DOD tours are from 36 to 48 months. Three possible alternatives exist within the application of this range of tour length.

1. Individual's normal shore tour is less than the area tour. In this case, the shore tour will be extended to coincide with the area tour. Other extensions normally will not be granted.
2. Individual's shore tour coincides with the area tour. No adjustments are necessary. Extensions will be considered on a case basis.
3. Individual's shore tour is longer than the area tour. Initial orders will be issued for the area tour. Upon request, an extension up to normal shore tour limits or 48 months total time in billet, whichever is less, may be granted. The total time counts as shore duty for rotation purposes; extension requests will be viewed accordingly.

Type 7—Partial Sea Duty: Duty performed in overseas landbased activities which is credited as shore duty for rotational purposes, but where members assigned receive partial sea duty credit in accordance with guidelines established by NAVPERS 15909-C, Article 4.0512.

Type 8—Double Sea Duty. Duty performed in commissioned vessels or activities in an active status which operates away from their homeport/homebase in excess of 150 days a year, but where due to the nature of their mission are awarded double sea credit for the tour served.

Q4. What type of duty would you be serving if you were assigned to a deployed cruiser homeported in Norfolk, Va.?

Q5. What type of duty would you be serving if you were assigned to a nondeploying ship?

DUTY PREFERENCES

An accurate and up-to-date Enlisted Duty Preference form, NAVPERS 1306/63 (dream sheet), should be on file with the detailers for each individual under their detailing responsibility. If you have never submitted a preference form, do it now. Without it, your detailer's only assumption is that your preference is simply **anywhere world**. You are encouraged to submit a new form at least 10 months prior to your projected rotation date (PRD). If you neglect to submit a new form prior to transfer, your detailer will assume that your old one is still correct.

Accurate information is important since it may affect your next duty assignment. However, after a few years, you probably will not remember what you put on your form. Make a copy of it for your files and break it out occasionally to check the information. As changes occur concerning service schools completed, number of dependents, desires, etc., submit a new form. Even minor changes should be reported. For example, most of us consider a change in the number of dependents to mean a new baby has been born. However, it is also a decrease in the number of dependents when your daughter gets married. With fewer dependents, you may be eligible for a wider range of duty assignments. Your assignability definitely improves with fewer dependents.

Eligibility for duties should be carefully investigated. If you are not qualified for the duties you have requested, your request is essentially invalid. If you are not sure of the qualifications required, check with your career counselor or personnel office for directives or instructions which may apply to the assignment you desire.

You should indicate a different choice in each of the preference boxes. This will maximize the possibility of your detailer assigning you to some type of duty you desire. The detailer will consider your first choice first and, if at all possible, will assign you to that duty. Therefore, nothing is gained by repeating your preferences. If assignment to your top choice is not possible, the detailer has to know your alternate selections to best fulfill your desires.

ANSWERS TO QUESTIONS Q2 AND Q3.

A2. Manpower Management.

A3. Entry, Rating, and Special.

The locations you indicate as duty preferences may be broad (anywhere 11th Naval District) or quite specific (Seattle; NTC, San Diego). Your chances, however, are much better with broad preferences, so it makes sense to include both. If your first choice is specific, add a broad area as the second or third alternative.

The Remarks section is particularly important. Include in your remarks any information which may influence your assignments. Following are a few important items that should be explained in the Remarks section:

Is your wife a teacher?

Do you speak a foreign language?

Do you have a handicapped child?

Do you have any special qualifications?

Do you have any deficiencies or physical problems that do not appear in your service record which might be a handicap in an instructor or shore patrol billet?

Do not confuse the Enlisted Duty Preference form with the Enlisted Transfer and Special Duty Request (NAVPERS 1306/7). These forms are not interchangeable; they serve two completely different functions. Essentially, the preference form is a permanent record maintained on file for use when you become available for routine assignment. On the other hand, the Enlisted Transfer and Special Duty Request form is used to request a single, specific program. Some of the types of duty that require NAVPERS Form 1306/7, or a letter request with specific information, are new construction, recruiting, drug abuse specialist, minority affairs, courier, and special projects (as they are initiated). If you are in doubt as to which form to use, call your detailer who will be happy to answer your questions.

Q6. What is the purpose of the NAVPERS 1306/63 form?

DETAILING

The job of a detailer is a thankless one. A detailer must treat each decision as if it is the most important decision he or she will ever make. Considering the instructions and the restrictions placed upon a detailer, the task seems impossible. However, a surprisingly high percentage of individuals are assigned to billets of their choice. Regrettably, every individual cannot be assigned to an area or billet of preference, and the detailer must be prepared to justify any decision made.

The basic policy governing the assignment of enlisted personnel is that every effort will be made by rating control officers and detailers to assign personnel to duty stations in accordance with their preferences. Assignments must also be commensurate with eligibility, availability of billets desired, and with the priorities established by the Chief of Naval Operations and the manning control authorities.

There are many potential variables that the detailer must consider in making a specific assignment. Taken together, they constitute a complex decision making process which may frequently give the appearance of a mystic rite. The following lists contain the individual, billet, and external variables most frequently considered by the detailer.

Individual Variables

Individual variables include:

1. Rate, rating, NEC—obviously the first considerations in any assignment.
2. Previous performance and evaluation of potential performance—particularly when considering assignment to special duties such as instructor and recruiter.
3. Specialized training or qualifications held, other than NEC-identified skills.
4. Service history, active duty base date, obligated service career status, and advancement status.
5. Career rotation status—sea/shore duty history and policy concerning current duty station (neutral duty, etc.).
6. Security clearance or clearability.
7. Training required to satisfy next assignment and career training pattern.
8. Applicable guarantees or incentives—first reenlistment incentive, twilight tour, etc.
9. Any special considerations known to the detailer—dependent's status, medical problems, etc.

Billet Variables

Billet variables include the following:

1. First there must be a valid billet vacancy to be filled, requiring a certain rate and NEC.
2. The assignment, when considered with all others of the rate involved, must contribute to maintain a balance in manning levels between the two fleets and other manpower users.

3. The assignment must respond to the established priorities.

4. The manning rules of the activity involved.

5. Activity employment schedule.

6. Any special rotation plans which apply to the activity.

7. Any special billet requirements—factory training, foreign language skill, special screening, security clearance, etc.

External Variables

External variables include, or may consider:

1. Cost of the move. All other factors being equal, the least costly PCS move is ordered. Detailers must assess such factors as distance involved, number of dependents, and location of household goods in arriving at cost judgments.

2. Time frames of PRDs, billet vacancies, class convening dates, leave and travel time, must all coincide.

3. Constraints imposed by higher authority. Overseas area tour lengths, number of dependents allowed, sole surviving son restrictions, etc.

4. Tour lengths for the type of duty, activity, location, and rating must dovetail with obligated service and career history of the individual.

These lists do not include all possible variables, but they certainly indicate that much thought, time, and effort go into making actual assignments. In matching the right person for the right job, the detailer continues to strive for more efficient manpower use which brings billets, skills, and personal desires into harmony and provides timely response to the Navy's changing manpower requirements.

ADVANCEMENT

The advancement system is another area in which you and the Navy have a mutually beneficial relationship. You benefit through higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. The Navy benefits from your advancement in two ways. First, you become more valuable as a technical specialist in your own rating. Second, you become more valuable as a person who can supervise, lead, and train others. It is important that you understand the advancement system and are aware of frequent changes. BUPERS Notices 1418 will usually keep you up to date.

The normal system of advancement may be easier to understand if it is broken into two parts:

1. Those requirements that must be met before you may be considered for advancement.
2. Those factors that actually determine whether or not you will be advanced.

QUALIFYING FOR ADVANCEMENT

In general, to qualify (be considered) for advancement, you must first fulfill the following:

1. Have a certain amount of time in service.
2. Have a certain amount of time in paygrade.
3. Demonstrate knowledge of material in your mandatory training manuals by achieving a suitable score on your command's test, successfully completing the appropriate NRTCs or, in some cases, successfully completing an appropriate Navy school.
4. Satisfy the requirements of the Personnel Advancement Requirement (PAR), NAVPERS 1414/4, program.

ANSWERS TO QUESTIONS Q4 THROUGH Q6.

A4. Type 2 (Sea Duty).

A5. Type 5 (Neutral Duty).

A6. To make your detailer aware of your duty preference.

5. Be recommended by your commanding officer.

6. Demonstrate knowledge of the technical aspects of your rating by passing a Navywide advancement examination based on the occupational standards applicable to your rate (from NAVPERS 18068 series—those standards listed at and below your rate level).

If you meet all the above requirements satisfactorily, you become a member of the group from which advancements will be made.

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all the requirements makes you eligible but does not guarantee your advancement. Some of the factors that determine which qualified persons will actually be advanced in rate are the score made on the advancement examination, the length of time in service, the performance marks earned, and the number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceeds the number of qualified personnel, most likely all of those qualified will be advanced. More often, however, the number of qualified people exceeds the number of vacancies. For those instances, the Navy has devised a procedure for advancing those who are best qualified. This procedure is based on combining three personnel evaluation systems:

Merit rating system (annual evaluation and CO's recommendation).

Personnel testing system (advancement examination score—with some credit for passing previous advancement exams).

Longevity (seniority) system (time in rate and time in service).

Simply, credit is given for how much the individual has achieved in the three areas of performance, knowledge, and seniority. A composite, known as the final multiple score, is generated from these three factors. All the candidates from a given advancement population who have passed the examination are then placed on one list. Based on the final multiple score, the person with the highest multiple score is ranked first, and so on, down to the person with the lowest multiple score. Advancement authorizations are then issued, beginning at the top of the rank-ordered list, for the number of persons needed to fill the existing vacancies.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the most in preparing for advancement. They were not content to just qualify; they went the extra mile in their training, and through that training and their work experience developed greater skills, learned more, and accepted more responsibility.

While it cannot guarantee that any one person will be advanced, the advancement system does guarantee that all persons within a particular rate will compete equally for the vacancies that exist.

A change in promotion policy, starting with the August 1974 examinations, changed the passed-but-not-advanced (PNA) factor to a high quality bonus point factor. Under this policy, a person who passed the examination but was not advanced could gain points toward promotion in subsequent attempts. Up to three multiple points can be gained in a single promotion period. A maximum of 12 points (for E-6) can be accumulated over the most recent five exams of the last six exam cycles. The addition of the bonus points factor, with its 12 point maximum, raises the total number of points possible on the final multiple for an E-6 from 252 to 264. This gives the examinee added incentive to keep trying for promotion in spite of repeated failure to gain a stripe because of quota limitations.

THE ADVANCEMENT HANDBOOK FOR PETTY OFFICERS

The Advancement Handbook for Petty Officers was written to help you prepare for advancement in your rating. It is presented in three parts:

Part A: The Navy Advancement System—provides valuable information about advancement paths, eligibility requirements for advancement, professional development, advancement examinations, and examination scoring.

Part B: Naval Standards/Bibliography—presents the role and function definitions for petty officers, naval standards, and the supporting bibliography. It provides a complete copy of the naval standards for paygrades E-4 through E-9.

Part C. Occupational Standards/Bibliography—presents the occupational standards and supporting bibliography for each rate within your rating. Occupational standards state the tasks you are required to be able to perform in your rating on a daily basis. They are the basis on which

Navywide advancement-in-rate examinations are developed.

You should obtain a copy of this handbook that has been developed specifically for the Gunner's Mate Guns (GMG) rating, from your ESO at your earliest opportunity. It is pocket-sized for your handling and stowage convenience. Every gunner should have his own personal copy.

ADVANCEMENT OPPORTUNITIES FOR SENIOR PETTY OFFICERS

Making E-6 is far from the end of the advancement line. In addition to the enlisted advancement path, advancement to warrant officer and commissioned officer are among the opportunities available to qualified petty officers. These special paths of advancement are open to personnel who have demonstrated outstanding professional ability, the highest order of leadership and military responsibility, and unquestionable moral integrity.

Your Next Step

After making E-6, your sights will be set on your next promotion, GMC. On smaller ships, you will, in all probability, be serving as the leading GM aboard. This will bring increased responsibilities and prestige.

The requirements for GMC include all the facets of both the GMG and GMM ratings. It goes without saying that the competition will be much greater at the E-7 level, since all qualified first class GMGs and GMMs will be "gunning" to meet the available quota.

Only two factors are included in the Final Multiple Score (FMS) for paygrade E-7 candidates: Exam standard score (60%) and the Performance Mark Average (40%). If you do sufficiently well on the examination, you will become Selection Board Eligible. Your service record will then go before the Chief Petty Officer Selection Board, which will determine the selectees. A discussion of selection board procedures can be found in *Military Requirements for Chief Petty Officer,* NAVEDTRA 10047.

Advancement to Warrant or Commissioned Officer

If you are interested in becoming a warrant or commissioned officer, ask your educational services officer for the latest requirements that apply to your particular case. See figure 1-1 for an illustration of the WO/LDO career path.

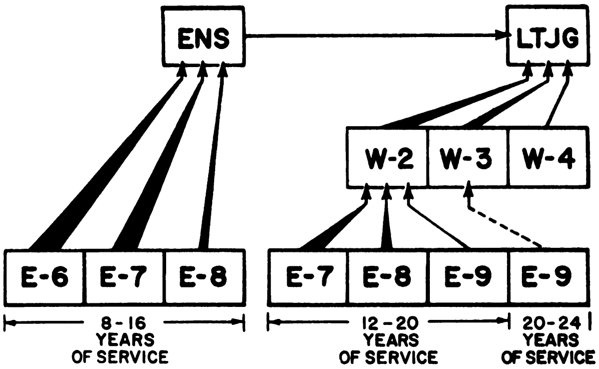
The warrant officer (WO) program provides the opportunity for E-7 and above enlisted personnel to advance to warrant rank.

The limited duty officer (LDO) program provides a path of advancement from warrant officer to commissioned officer. LDOs are limited, as are WOs, to duty in the broad technical fields associated with their former ratings. E-6s, to be eligible, must have passed an E-7 rating exam prior to selection.

Q7. *In what minimum paygrade must you be serving to qualify for a commission under the LDO program?*

SUMMARY

Advancement to E-6 will be a significant milestone in your naval career. While your responsibilities in your occupational specialty will necessarily increase, these responsibilities will shift more toward the supervisory role. You will be more involved with the planning and supervision of work, and with teaching new skills. In this chapter we have included a discussion on the need for effective communications, training, classification and sequence codes, duty assignments, types of duty, and advancement opportunities.



200.29

Figure 1-1.—Senior petty officer career path to LDO/WO.

REFERENCES

The following reference materials were used to develop the information presented in this chapter.

Bibliography for Advancement Study, NAVEDTRA 10052-AJ, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1987.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, Section II, NAVPERS 18068-E, Bureau of Naval Personnel, Washington, D.C., 1986.

Enlisted Transfer Manual, NAVPERS 15909-C, Naval Military Personnel Command, Washington, D.C., 1979.

ANSWER TO QUESTION Q7.

A7. E-6.

CHAPTER 2

SYNCHROS AND SERVO SYSTEMS

Synchros are used in servo systems to control the position and movements of fuze setters, sight-setting equipment, and the power drives of gun, turret, rocket, and missile launchers. Synchros are used as position-sensing devices to convert mechanical signals to electrical signals or to convert electrical signals to mechanical signals. Synchros are also used in servo systems for rapid data transmission between components of a ship's weapon system.

It is beyond the scope of this book to examine each type of synchro individually. The purpose of this chapter is to provide extensive information on synchros and servo systems as they relate to ordnance equipment. Additional references on the construction and principles of operation, as well as the basic operation of servo systems can be found in the Navy Electricity and Electronics Training Series (NEETS), Module 15, *Principles of Synchros, Servos, and Gyros,* NAVEDTRA 172-15-00-85; the *United States Navy Synchros, Description and Operation Handbook*, MIL-HDBK-225(AS); and the *United States Navy Synchros, Description and Operation*, OP 1303. A basic review of ordnance application of synchros is found in *GMG 3 & 2*, NAVEDTRA 10185-C1.

SYNCHROS

Synchros are seldom used alone. They work in conjunction with one another, and when two or more synchros are interconnected to work together, they form a synchro system. Such a system may, depending on the types and arrangement of its components, be put to uses which vary from positioning a sensitive indicator to controlling the motors which move a gun mount weighing many tons. If the synchro system provides a mechanical output which does the actual positioning, as in the case of the indicator, it is referred to as a torque system. If it provides an electrical output which is used only to control the power that does the mechanical work, it is referred to as a control system. Control synchros are usually part of a larger system called a servo (automatic control) system. In many cases, the same system is called upon to perform both torque and control functions. Individual units are designed for use in either torque or control systems. Some torque units may be used as control units, but control units cannot replace torque units.

Synchros are grouped according to their intended function. The seven most common types or functional classifications, are clearly outlined in NEETS, module 15.

TORQUE SYNCHRO SYSTEMS

The individual synchros which make up a torque system are designed to meet the demands placed on them by the mechanical load that such a system is expected to handle.

TRANSMITTER AND RECEIVER

The simplest synchro system consists of one torque transmitter (TX) and one torque receiver (TR) connected in parallel (fig. 2-1).

It should be emphasized here that the chief difference between the transmitter and receiver is one of function. The transmitter is the unit whose shaft is turned; the receiver is the unit whose shaft follows. Remember, they are not always interchangeable. Electrically they are identical, but the receiver usually has an inertia damper and certain other refinements which are not present in the transmitter. Forces equal and opposite to those turning the receiver rotor are present in the transmitter but do not affect its rotor position because the rotor is not free to turn. In practice, the transmitter rotor is mechanically connected, usually by gears, to the mechanism furnishing the information to be transmitted.

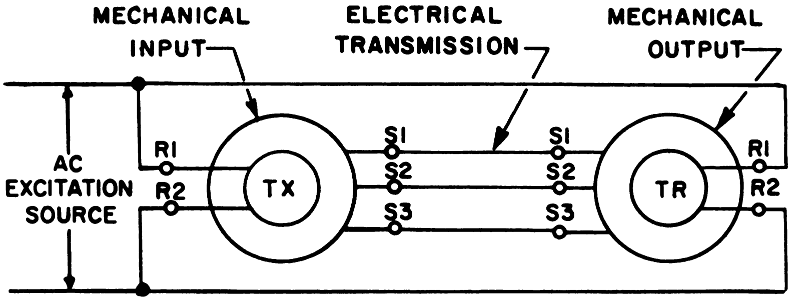


Figure 2-1.—External connections of a transmitter-receiver system.

The outstanding characteristic of the transmitter-receiver system is that, as soon as both rotors are connected in parallel to the same ac source, the receiver rotor assumes and holds the same electrical position as the transmitter rotor. Naturally, because of phase relationship, the transmitter and receiver are energized from the same ac source; otherwise, the system could not function properly. If the transmitter is positioned at 0°, the receiver rotor turns to and remains at 0°. If the transmitter is turned to 30°, the receiver turns with it to 30°.

An example of using a simple synchro system is to indicate the position of a controlling director. A torque transmitter (TX) is connected mechanically to a controlling director and connected electrically to a torque receiver (TR) located in the indicating section of a gun/missile plotting room or weapons control station. The indication is in the form of dial readings mechanically connected to the rotor of the TR.

Q1. What is the primary difference between a synchro transmitter and a synchro receiver?

TORQUE SYNCHRO SYSTEMS CONTAINING DIFFERENTIAL UNITS

The demands on a synchro system are not always as simple as the positioning of an indicating device in response to the information received from a single source. For example, an error detector used in checking fire control equipment employs a synchro system to determine the error in a gun's position with respect to the training order supplied by a dummy director. To do this, the synchro system must accept two signals, one containing the training order and the other giving the gun's actual position. The system must then compare the two and position an indicator to show the difference between them, which is the error.

Obviously, the simple synchro transmitter-receiver systems considered up to this point could not handle this job. A different type of synchro must be included in the system, one which can accept two position-data signals simultaneously, add or subtract the data, and furnish an output proportional to the sum or difference which it finds.

This is where the synchro differential comes into the picture because it can perform all three of these functions.

Refer to MIL-HDBK-225(AS), OP 1303, and NEETS, module 15, to understand more about how addition and subtraction results are accomplished in differential transmitters and receivers, as well as their application in naval ordnance.

FACTORS THAT AFFECT THE ACCURACY OF A TORQUE SYNCHRO SYSTEM

The accuracy of a synchro system is probably its most important characteristic. Torque system accuracy is determined by how closely the system's output shaft approaches the position indicated by the system's input or inputs. In such a system, perfect accuracy is never obtained. Regardless of how carefully receivers are constructed, electrical error and an error due to friction and load (called receiver error) are always present. A small but measurable amount of torque is required to overcome this friction, and when a receiver rotor is in perfect alignment with the signal applied to its stators, no torque is produced. The receiver lags slightly before producing enough torque to overcome brush and bearing friction, and this lag is present as an error to any torque system.

Simple Torque Systems

In a torque receiver consisting of one transmitter and one receiver, two important factors must be considered to obtain maximum accuracy: (1) the friction on the shaft of the receiver must be reduced to an absolute minimum; and (2) the torque gradient of the receiver must be relatively high with respect to its combined friction and load, so that a very small lag produces sufficient torque to overcome both.

To satisfy these requirements, the ball bearings used on synchro receivers are selected with extreme care and are factory-lubricated according to strict military specifications. Also, both the transmitter and receiver must be large enough and have sufficient torque gradient to meet the needs of the system.

Torque Systems Involving a Number of Receivers

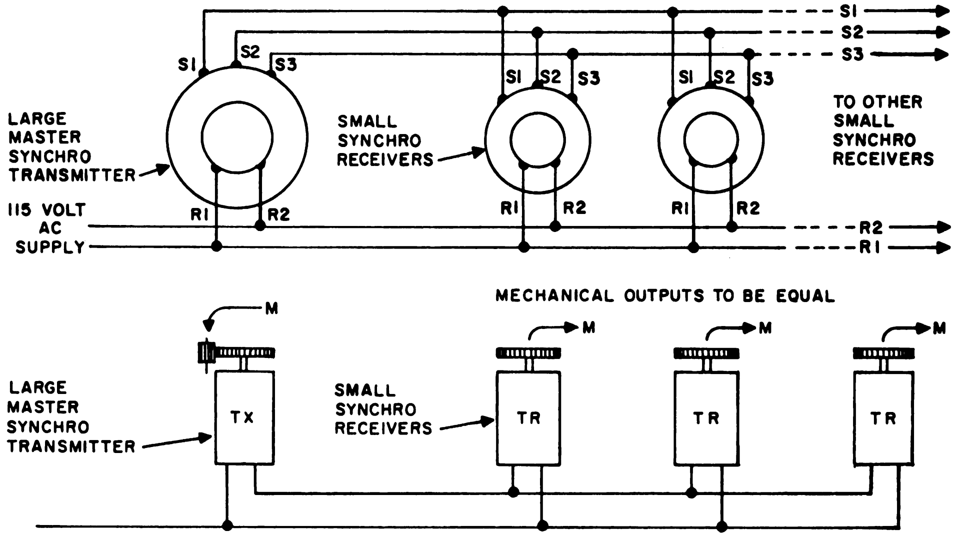
In a torque system where either a TX or TDX drives several receivers, the accuracy with which each receiver follows the position-data signal applied to its stators is determined by the following factors.

1. The friction and load on the shaft of that receiver.
2. The friction and loads on the shafts of all the other receivers. If any one of the receivers is excessively loaded or becomes jammed, the accuracy of the whole system is affected.
3. The torque gradient of each receiver is related to the number and size of the receivers being driven by the transmitter. If too many receivers are connected to a particular transmitter, its output voltages are reduced and an excessive overall lag is produced in the system.

One Transmitter With Many Receivers

One large synchro transmitter may be used to drive a number of small synchro receivers connected in parallel, if the impedance of the transmitter stator windings is low enough to supply the current necessary to activate all the receivers without excessive voltage drop.

If one synchro receiver has to supply more torque than the others, its shaft will lag further behind the transmitter's producing less opposing voltage in its stator coils and, therefore, drawing more current than other receivers. This increased current will lower the synchro transmitter's output voltage, causing the other receivers to lag more than before. For accuracy, it is essential that the synchro transmitter have low impedance (a high unit torque gradient), and that the load on each synchro receiver be as low as possible. Equal loads are important. In the multiple system, any unnecessary load on any one synchro receiver affects the accuracy of the entire system. A diagram and symbols are used to show the action in figure 2-2.


S1
S2
S3
S1
S2
S3
S1
S2
S3
S1
S2
S3
LARGE MASTER SYNCHRO TRANSMITTER
SMALL SYNCHRO RECEIVERS
TO OTHER SMALL SYNCHRO RECEIVERS
115 VOLT AC SUPPLY
R1
R2
R1
R2
R1
R2
R2
R1
MECHANICAL OUTPUTS TO BE EQUAL
M
M
M
M
LARGE MASTER SYNCHRO TRANSMITTER
TX
SMALL SYNCHRO RECEIVERS
TR
TR
TR

53.256

Figure 2-2.—One transmitter, many receivers.

An advantage of a synchro system is that the moment a signal is fed into the synchro transmitter, the data is immediately and simultaneously transmitted to all receiver stations, regardless of how remote or isolated each may be from the others on the ship. Another advantage, from the military standpoint, is that the knocking out of a receiver station will not interfere with the operation of the remaining units of the system.

Q2. What types of errors are always present in a torque synchro system?

ORDNANCE APPLICATIONS OF TORQUE SYNCHRO SYSTEMS

Torque synchro systems are still used in naval ordnance equipment. In the familiar 5″/38 gun mount, gun train and elevation orders are relayed to the mount through a torque synchro system. In automatic control, torque-type synchros receive the gun order signals from a director or plot and, by mechanically positioning a fine pilot valve, control the mount's power drive. In local control, a "follow-the-pointer" system is used in which the pointer and trainer control mount movement with their handwheels and follow train and elevation orders as indicated on their dials. A similar indicating system is employed to transmit sight-setting and fuze-setting orders to the mount—all using torque synchro systems. Down in plot, own ship's course and speed are transmitted to the Mk 1A computer from the ship's gyro and pitometer log (referred to as the pit log) by means of a torque synchro system. Although torque synchro systems have varied uses, they are principally used for indicating or data transmission purposes because of their inability to position with any accuracy anything but very light loads.

An example of the use of a synchro configuration using a TDR, TX, and a TR, is found in star shellfire. Gun elevation is computed and the data mechanically cranked into the TDR as star shell elevation orders. Star shell spots are corrected by mechanical inputs to the TX (fig. 2-3). The corrected signal is sent to the TDR by the TX whose values make up the elevation gun order signal sent to the TR at the gun as elevation star shell position orders.

Q3. What is the principal use of torque synchro systems?

CONTROL SYNCHRO SYSTEMS

The comparatively small mechanical output of a torque synchro system is suitable only for very light loads; and even when not heavily loaded, a torque system is never entirely accurate. The receiver rotor requires a slight amount of torque to overcome its static friction, and this torque can only be produced by a small error in the system. Torque systems place a drag on associated equipment, which affects their accuracy.

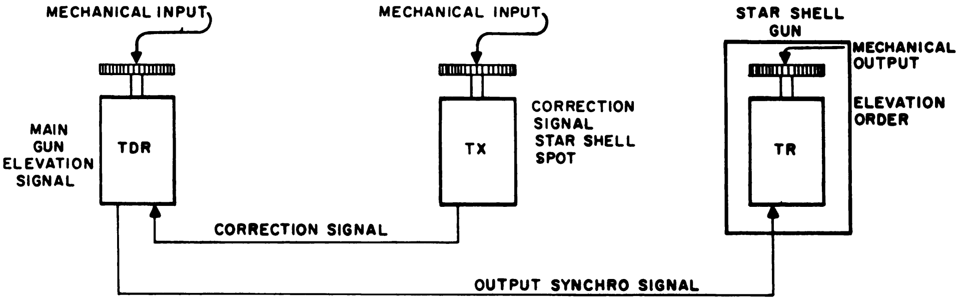
When larger amounts of torque or a higher degree of accuracy, or both, are required, torque synchro systems give way to control synchros used as components of servo systems. Synchros control the servo system; the servos provide the torque or power.

THE ROLE OF THE CT

Assume a synchro configuration is required to train a gun and that a CX will be used with a CT for this purpose (fig. 2-4). The CX rotor receives power from the ac supply. The operator will crank in, as a mechanical input, a particular setting. This will cause the CX stator to transmit a specific primary voltage to the CT stator and, in turn, induce secondary voltage in the rotor winding of the CT. This secondary voltage,

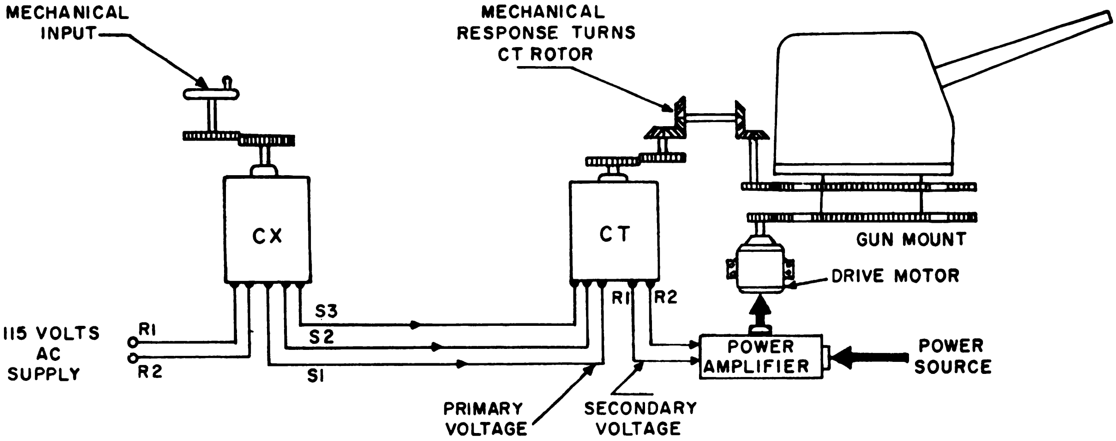
ANSWER TO QUESTION Q1.

A1. The function—In the synchro transmitter, the shaft is turned; in the synchro receiver, the shaft follows.



53.257

Figure 2-3.—Star shell fire.



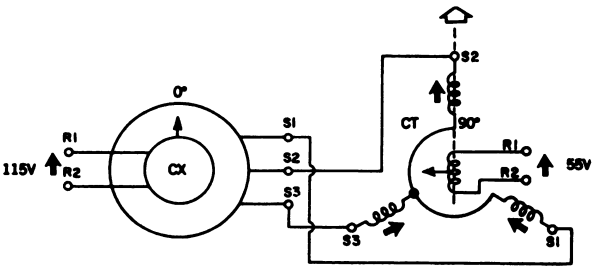
53.258

Figure 2-4.—Synchro configuration (gun train).

transmitted over leads R1 and R2, is used by the power amplifier to control the operation of the drive motor for the training of the gun. The gun mount, in turn, is geared to the rotor of the CT to provide the mechanical response. When the rotor of the CT has been turned by response to an amount equal to the signal from the CX, the output voltage from the CT drops to zero, and the signal to the amplifier ceases. This causes the power motor to cease operation. Thus the gun has been trained to correspond to the original signal cranked into the system. The CT rotor is brought into correspondence within a fraction of a second after mechanical input to the synchro transmitter stops.

OPERATION WITH A SYNCHRO TRANSMITTER

Consider the conditions existing in the system shown in figure 2-5, where a CT is connected for operation with a CX and the rotors of both units are positioned at 0°. The relative phase of the individual stator voltages with respect to the R1 to R2 voltage of the transmitter is indicated by small arrows. The resultant stator field of the CT



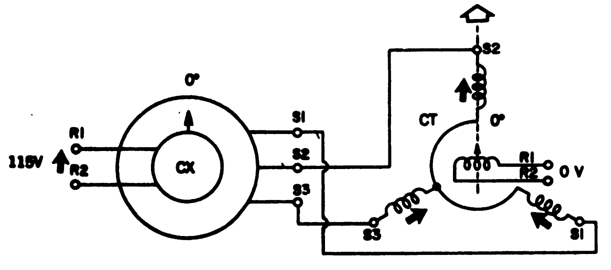
53.21

Figure 2-5.—Conditions in CX-CT system with rotors in correspondence.

is shown in the same manner as for the TDX. With both rotors in the same position, the CT stator field is at right angles to the magnetic axis of the rotor coil. Since no voltage is induced in a coil by an alternating magnetic field perpendicular to its axis, the output voltage appearing across the rotor terminals of the CT is zero.

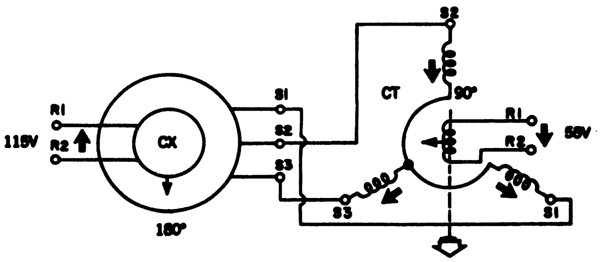
Now assume that the CT rotor is turned to 90° (fig. 2-6), while the CX rotor remains at 0°. Since the CT's rotor position does not affect its stator voltages or currents, the resultant stator field of the CT remains aligned with S2. The axis of the rotor coil is now in alignment with the stator field. Maximum voltage, approximately 55 volts, is inducted in the coil and appears across the rotor terminals as the output of the CT.

Next, assume the CX rotor is turned to 180° (fig. 2-7). The electrical positions of the CX and CT are 90° apart, the CT stator field and rotor axes are aligned, and the CT's output is again maximum, but the direction of the rotor's windings is now reversed with respect to the direction of the stator field. The phase of the output voltage is, therefore, opposite to that of the CT in the preceding example. This means that the phase of the CT's output voltage indicates the direction in which the CT rotor is displaced with respect to the position-data signal applied to its stators.



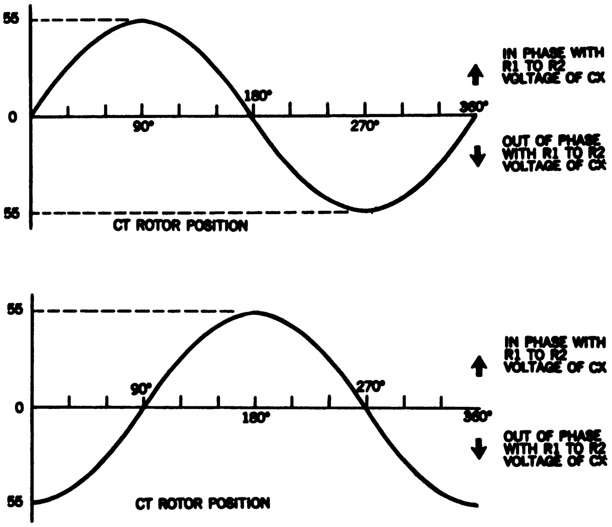
53.22

Figure 2-6.—Conditions in CX-CT system with CX rotor at 0° and CT rotor at 90°.



53.23

Figure 2-7.—Conditions in CX-CT system with CX rotor at 180° and CT rotor at 90°.



12.165

Figure 2-8.—CT output voltage.

It is evident that the CT's output can be varied by rotating either its rotor or the position-data signal applied to its stators. It can also be seen that the magnitude and phase of the output depends on the relationship between signal and rotor rather than on the actual position of either. The graphs in figure 2-8 illustrate the difference in the CT output when the CT rotor is first rotated through 360° with the CX rotor at 0°, and with the CX rotor at 90°.

TURNING CX ROTOR

The turning of the CX rotor causes four things to happen in the CT: (1) magnetic fields in the

ANSWERS TO QUESTIONS Q2 AND Q3.

A2. Electrical error and receiver error.

A3. Indicating or data transmission.

CX and the CT are caused to rotate; (2) voltages are induced in the CT's rotor; (3) polarity of the CT's rotor leads, with respect to voltage energizing the CX's rotor becomes established; and (4) response gearing rotates the CT's rotor toward the position of correspondence.

The important points to remember about the operation of a CT are (1) when the CT's rotor is in the same electrical position as the position-data signal applied to its stator (that is, in the same position as the resultant stator field), the electrical output of the unit is zero; (2) when displacement with respect to each other is less than 90°, any change in the angular relationship between the rotor and the position-data signal produces a corresponding change in the magnitude of the CT's output; and (3) the direction of CT rotor displacement with respect to the position-data signal is always indicated by the phase of the CT's output voltage.

As indicated in figure 2-8, the electrical output of the CT is also zero when the rotor is displaced with respect to the position-data signal by 180°. It is, therefore, necessary to identify which 0-volt CT rotor position indicates agreement with the signal. In the case of the simple CX-CT combination, this is done by the phases of the two rotor voltages. If the CX and CT rotors are in the same position, the CT rotor voltage is zero; turning the rotor slightly counterclockwise from the 0-volt position produces a voltage from R1 to R2 on the CT that is in phase with the voltage from R1 to R2 on the CX.

In practical applications of the CT, its rotor is positioned for proper operation in a particular system by using the zeroing procedures required for that system. This subject is addressed later in this chapter. Consideration of the servo systems (discussed in subsequent sections of this chapter) also shows that a 180° displacement of the CT rotor can usually be detected in the behavior of the system's output.

ERRORS IN CONTROL SYNCHRO SYSTEMS

Three factors which produce errors in control systems are electrical error, errors inherent in CTs, and errors resulting from the use of torque and control units in the same system.

Electrical Error

The difference between the actual physical position and the electrical position of a synchro is known as electrical error. Consider a control system consisting of a CX and a CT. If the CX and CT each have an electrical error of 12 minutes, the total possible error is 24 minutes. Adding a CDX having an electrical error for rotor and stator of 10 minutes each to this system, the total error increases to a possible 44 minutes or about three-quarters of a degree. The effect of such an error depends on the use of the particular system. In a gun training system, a 1/2-degree or 1-degree error becomes more pronounced at increased distances. The fact that CXs, CDXs, and CTs are driven does not make them free from electrical errors. Manufacturing irregularities in the windings and the magnetic structure are inherent in all synchros.

Errors of Control Transformers

In a simple CX-CT system, it usually is assumed that the null position for the CT rotor always occurs when the axis of the CX and CT rotors are at 90° displacement; however, this is seldom true. As an example, if a CX and CT are so positioned that the CT output is minimum and then the CX rotor is turned exactly 15°, the CT rotor usually must be turned slightly more or less than 15° to again obtain a null reading. Note that a null or minimum reading, rather than a zero reading, has been specified. The voltage output of a CT never becomes zero but, generally at correspondence, falls as low as 50 to 125 millivolts for 115-volt synchros. Also, the null voltage obtained varies as the CX rotor position is varied. It is the usual practice in a servo for the system to operate in such a manner that the CT output is a null. It should be obvious, therefore, that any variation in the position at which a null is obtained is reflected as an error in the entire system. Corrective measures also must be taken to compensate for phase shift in a servo. The impedance of the synchro windings cause the CT voltage to lead the CX supply voltage.

In a system where more than one CT is used, if the drive to one of the CTs is inoperative, that CT may introduce error into the system which increases as the angle between its correct and actual position increases.

When CTs are rotated at high speeds, an additional error (known as speed error) may be introduced. The null voltage position of the CT no longer occurs when the CT rotates at synchronous speed with the CX, but occurs when the CT rotor is at an angle to its correct synchronous position. The angle depends upon the speed of rotation, and usually lags behind that obtained under static conditions. As the number of CTs in a system increases, the speed error is apt to increase. Also, the speed error for a given speed is comparatively larger for a smaller size transmitter. However, speed error is usually negligible until approaching synchronous speed for the excitation frequency involved. For the usual two-pair synchros, this is approximately 2,800 rpm for 60 hertz and 19,000 rpm for 400 hertz units. Considering CTs of the same size and rotating at the same speed, the speed error is, therefore, considerably less for 400 hertz units than for 60 hertz units.

Use of Torque and Control Units in Same System

Some systems use both torque and control units; however, the use of torque units in a control system is usually avoided where accuracy is of prime importance.

In addition to electrical error, TRs and TDRs are subject to receive error, the difference between the position assumed by the TR or TDR, and the position transmitted by the TX, which often is as great as 1°. Receiver error, also called position error, is caused by brush and bearing friction and actual TR load. Any increase in friction or load on a TR or TDR, or adding more TRs or TDRs to the system, increases the resultant bus error. Smaller TRs have such a low torque gradient value that, as lubrication deteriorates with use and bearings become dirty, the receiver error increases. TRs are also subject to oscillations, and irregular or excessive oscillations are reflected as an additional circuit error. When torque and control units are used in the same system, excitation must be supplied by a TX rather than a CX.

Q4. What three factors produce errors in synchro control systems?

ORDNANCE APPLICATIONS OF CONTROL SYNCHRO SYSTEMS

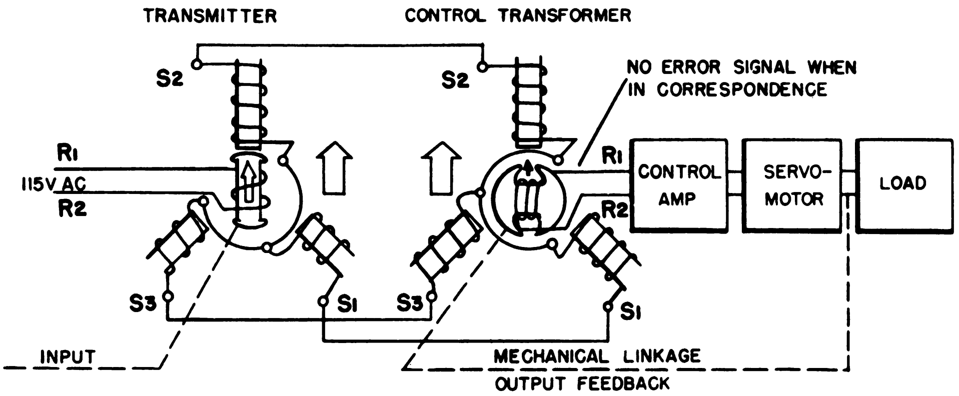
Control synchro systems are, as previously stated, usually part of a larger system called a servo system. A familiar example of such a system is the Mk 35 amplidyne power drive which is used in the twin 3"/50 gun mount. This drive system will be described in the next two chapters of this manual.

Control synchros are also used in the receiver-regulators for the 5"/54 Mk 42 gun mount. The control equipment for the 5"/54 Mk 42 gun mount will be described in chapter 6 of this manual.

CTs are often used as error detectors in a servomechanism system which may be used to control the movement of a gun mount, a small indicator motor, or many other such loads (fig. 2-9). More information on servomechanisms and servo systems (which are much the same thing) will follow in this chapter.

SYNCHRO CAPACITORS

In a circuit where a CX is supplying a signal to a differential unit or CT, the transmitter is supplying a lagging current to the stator of the differential unit or control transformer. To minimize the amount of current lag and, thereby, improve the accuracy of the system, a capacitive network is placed in the circuit. This network is generally termed a synchro capacitor, even though the network contains three individual capacitors



53.259

Figure 2-9.—The control transformer as an error detector.

and the total capacitance of all three capacitors is the rated value of the network. The three capacitors are delta-connected as shown in figure 2-10, view A, and are connected in parallel with the stator windings of the differential unit and CT (figure 2-10, view B). The connections are made as short as possible, as high currents in long leads increase the transmitter load and reduce the system's accuracy.

Synchros capacitors decrease the line current drawn by synchro systems and, in effect, increase the torque of the synchro receivers in the system. This effective increase in torque near the point of synchronization increases the accuracy of the overall system.

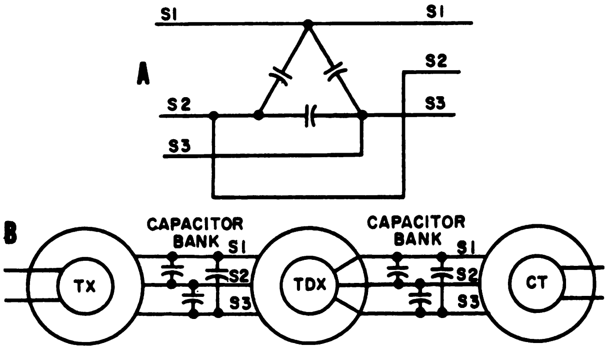
Currents present in the stator circuits of a TX-TR synchro system are a result of a voltage difference between the stators. If the synchros are in correspondence, there is no voltage difference and, hence, no current in the stator circuits. Therefore, capacitors are not required in a TX-TR synchro system.

Q5. In a servomechanism used to control movement of a gun mount, what purpose is served by the CTs (control synchros)?

Q6. What is the purpose of synchro capacitor?

SERVOMECHANISMS AND SERVO SYSTEMS

Electrical arrangements that cause mechanical action to take place automatically in response to synchro signals are called servo systems or servomechanisms. A servomotor is one of the components of a servo system. A servomotor is a reversible motor that operates in a slave-to-master relationship with the synchro equipment from which it receives its input signals. There are both ac and dc types of servomotors. The servomotor used in amplidyne power drives is a dc type. Certain dials and mechanisms in computing equipment are turned by ac types.



12.279

Figure 2-10.—Synchro capacitors.

Figure 2-9 illustrates the elements of a servo system. The functioning of such a system is described below with reference to how its principle is used in positioning a gun.

1. At a remote station, all available information about the target is collected and combined. A pair of order signals is transmitted to the gun mount telling what values of train and elevation will put the gun in firing position.
2. The order signal is compared with the actual position of the gun. The result of this comparison is a command (called the error signal) telling how far and in which direction the gun must move.
3. When properly amplified, the error signal operates the controls of a power drive.
4. The power drive moves the load in such a way as to reduce the error.
5. While the load is being driven, a response signal is sent back continuously and automatically for comparison with the order signal.
6. When the two error signals (train and elevation) have been reduced to zero, the gun is in the ordered position for firing.

SERVO PRINCIPLES

Now consider how the servo principle is applied in a typical servomechanism or servo system using an ac reference voltage. Compare figures 2-4 and 2-9. In figure 2-4 the parts in the mechanism corresponding to the diagram of figure 2-9 are a CT which serves as the signal receiver and comparison device, an electronic amplifier, and an ac servomotor, which together correspond to the power drive and gearing from the motor which drives the load and the CT rotor. The amplifier may be of the tube-, magnetic-, or transistor-type, or a combination. The load may be a dial, a computing device, a launcher, a gun mount, etc.

The input that starts the servomotor is the output voltage of the synchro control transformer. This voltage has to be amplified before it can be used. As the servomotor turns in response to the input voltage, the rotor shaft furnishes a mechanical output to the gearing that turns the load.

The load in figure 2-4 is connected back, through gearing, to the rotor of the synchro control transformer. The result of this mechanical feedback is to drive the rotor in such a direction as to reduce the electrical output of the control transformer. When the load reaches the position originally ordered, the output of the control transformer becomes zero, and the motor stops.

The example chosen is a common type of servomechanism, but many other configurations are possible. It is possible to use a mechanical differential, an electrical resolver, a synchro differential transformer, a special type of movable-core transformer, or any of several other devices for the error-sensing unit. The variety possible in amplifiers has already been mentioned, as well as in auxiliary circuits and devices. Several kinds of motors are available, but the same servo principle underlies all these combinations.

The output drive motor in a servo system should have the required power, be easily reversible, and be capable of speed control over a fairly wide range. Ordinarily, an ac motor cannot fulfill the requirements of a servo drive motor as completely as a dc motor because the range of speed control is less. However, the use of an ac motor may provide a much simpler drive system, especially where ac power is the only source available and where some sacrifice in range of speed control can be made.

Q7. A load (gun mount) reaches the position originally ordered. What is the output of the control transformer at this moment?

SERVO TERMINOLOGY

Before going on into the larger and more elaborate servo system, we should become more familiar with some of the specialized terms that are used in connection with servo systems. The most common terms are defined here.

OPEN-CYCLE CONTROL of a servo system means actuation of the servo solely by means of the input data, the feedback device being either removed or disabled. It should be clearly understood here that any mechanism must include a feedback provision to be classified as a servo; but in testing certain servo characteristics, an open-cycle control is often useful. Under such conditions, the elements involved are frequently referred to as an open servo loop.

CLOSED-CYCLE CONTROL refers to normal actuation of the system by the difference between input and output data, with the feedback device operative.

CONTINUOUS CONTROL is used to describe uninterrupted operation of the servo system on its load, regardless of the smallness of the error. All systems considered in this manual exercise continuous control; however, there are systems which do not.

DEVIATION or error of a servo is the difference between input and output.

ERROR SIGNAL or error voltage is the corrective signal developed in the system by a difference between input and output.

INSTRUMENT SERVOS and POWER SERVOS are designations used to classify servomechanisms according to their power output. An instrument servo is one rated at less than 100

ANSWERS TO QUESTIONS Q4 THROUGH Q6.

A4. Electrical error, error inherent in CTs, and error resulting from the use of torque and control units in the same system.

A5. As error detectors.

A6. To minimize the amount of current lag and to improve the accuracy of the system.

watts maximum continuous output; a servo with an output rating exceeding this amount is a power servo.

DUAL-SPEED SYSTEM

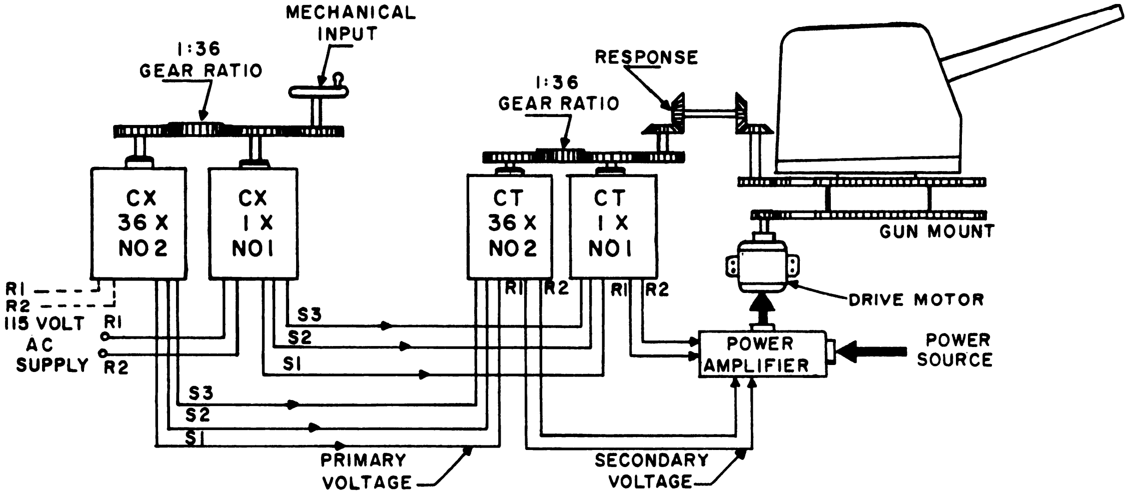
The 1-speed system, described so far in this chapter, is geared so that 1-degree movement of the mount or gun is equal to 1-degree movement of the synchro control transformer (CT). This system is used for getting the mount or gun into approximate correspondence with the position order signal. It does not, however, provide the required accuracy at the point of correspondence.

To obtain better control of a mount or gun system, two synchros are used, 1-speed (1X) for coarse control and 36-speed (36X) for fine control as shown in figure 2-11. For simplicity, the two systems are referred to as the 1X and 36X synchros. Only one synchro output is used at any one time. The 1X synchro is used when the position error signal is greater than 2°. The 36X synchro is used when the position error signal is less than 2°. Synchro selection (changeover) takes place in the servo amplifier or receiver regulator, depending on the type of power drive used. Most dual-speed synchro systems are designed so that synchro changeover from the coarse CT to the fine CT takes place within 2.5° of synchronization, but can differ depending on the type of gun system. Synchro changeover can occur at 2°, 2-1/2°, or 3° of synchronization. Both the 1X and 36X CTs are geared to the response mechanism from the gun or mount.

If the 1X synchro is rotated 90°, it is the equivalent to 90° of rotation of the mount. In the 36X system, however, a rotation of 90° of the 36X synchro is equal to only 2-1/2° of mount rotation.

A basic dual-speed synchro system consists of two transmitters (CXs) and two receivers (CTs). One CX (#1) receives the external input to the system and, through a network of gears, passes the effects of the external input to the second CX (#2) (fig. 2-11). The gear ratio between the two CXs determines the two specific speeds which the system will use to transmit the input data. If, for example, the gear ratio between the two CXs is 1:36, one revolution of the rotor of the first CX causes 36 revolutions of the rotor of the second CX. Thus, the first transmitter (the one which accepts the external input) is called the coarse CX, and the second one is called the fine CX. The outputs of each CX are passed through standard synchro stator connections to two CTs. One CT receives the coarse signal and the other receives the fine signal. The two CTs are connected by gears similar to the ones between the two CXs. For continuously accurate operation, CT gearing is essential.

In a 1X and 36X synchro system, one revolution of the rotor of the coarse CX causes 36 revolutions of the rotor of the fine CX. While the rotor of the coarse unit makes one revolution, it passes its 0-degree reference or synchronization point only once. Meanwhile, however, the rotor of the fine unit passes its synchronization point 36 times. The significance of this latter statement is that the fine CT has 36 synchronization points.



53.260

Figure 2-11.—Dual-speed system.

Only one of these apparent points, however, can be the true synchronization point.

If, while the synchro system is deenergized, the rotor of the fine CT is moved one complete revolution but the rotor of the coarse CT is not moved, the output of the fine CT would be in error when power is restored. To prevent this possibility, gearing is placed between the two CTs. Hence, the rotor of one CT mechanically follows the movement of the other. Therefore, this gearing is one method of removing the synchronization uncertainties of the fine CT and, in turn, from the system. The transmission of the torque-type and control-type two-speed synchro systems is geared the same way.

The receiver of a control-type servo system is a CT. Because the rotor of a CT is not energized, the error voltage induced into the rotor can be zero at two positions; the correct 0-degree reference position, and 180° from the correct position. This feature complicates the problem of false synchronization by doubling the number of apparent synchronization points. This problem is corrected by adding a stick-off voltage in series with the CT rotor circuit. A discussion of this corrective measure is detailed in chapter 6 of this text.

The main disadvantage of the 1X and 36X synchro systems is that the servo system is no longer self-synchronous. In the 1-speed synchro system, the output shaft is synchronized with the input shaft at only one point. In other words, there is only one position that the output shaft can assume which will allow correspondence between the rotors of the CT and the CX. We know that in the 36X system, however, the CT can be in correspondence at 36 different positions for any one position of the input shaft of the CX. For example, if the rotor of the CX is at 80° (fig. 2-12), the output shaft and, consequently, the gun or mount could be synchronized at 90°, 80°, 70°, and so on, in steps of 10°. In each of these positions of the CT's rotor, the position of the CT is stepped up 36 times so that it is an integral multiple of 360° thus bringing the CT into false correspondence with the CX in each case.

Because of this, the fine synchro system is never used by itself; since, as you have seen, it does not provide true synchronization of its input and output at all times. We certainly do not want a gun pointed at 60° when the CX is positioned at 80°. Therefore, the fine system is always combined with a coarse system. The fine synchro system provides a very sensitive control at times when the error between the order signal and the servo output is small. Since this is a 36X synchro, however, it can bring the gun to any one of 36 positions. It is the job of the coarse synchro system to bring the gun mount close enough to the true synchronous position so that it is within the range of the fine synchro.

Therefore, you must have some way for the coarse synchro to take control and drive the launcher into correspondence whenever the error exceeds a certain amount—in most cases about 2°. The circuits that accomplish this have many names. Some of these are as follows:

1. Synchro changeover circuit
2. Synchro crossover network
3. Synchronizing circuit

The switching elements used in these circuits could be relays, transistors, or electron tubes. How these circuits function to accomplish synchro changeover is explained in chapters 3 and 6 of this text.

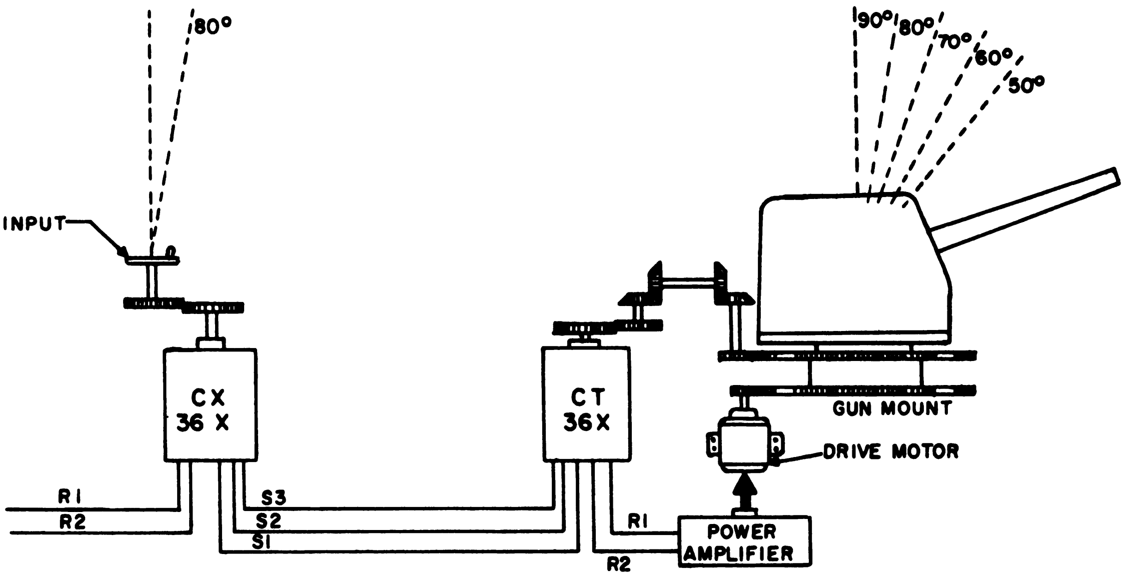
Q8. Is the 1-speed (1X) synchro used for coarse or fine tuning control of a mount or gun system?

CHARACTERISTICS OF SERVO SYSTEMS

A servo system must operate smoothly, rapidly, and with as few errors as possible. The motion and position of the servo system's output should duplicate the motion and position of the input. We do not get an ideal performance from servo systems because they do not react immediately to a change in order signal. The output will always lag the input. Any action of the output of a servo system, regardless of what

ANSWER TO QUESTION Q7.

A7. Zero.



53.261

Figure 2-12.—Fine synchro system can cause gun to synchronize at any multiple of 10°.

it is, requires time to take place. The output of a servo system (which could be electrical, mechanical, hydraulic, or any combination of these) requires a reaction time, which causes the output to lag behind the order signal; the order signal causes a servo system to function. Any lost motion in mechanical linkages or gearing will produce a delay. In hydraulic units, the expansion and contraction or the heating up of hydraulic fluids causes a lag to the flow of hydraulic fluids through hydraulic lines and slows the movement of hydraulic pistons and valves. In the electrical section of a servo system, the elements between the input device and the output device such as transformers, filter capacitors, and electrical or electronic couplings contribute somewhat to the time difference between the input signal and the output motion.

One method of increasing the speed in which a servo answers an input signal is to increase the gain of the amplifier which serves the system. The gain in a servo system is the ratio of change in output motion to a change in input voltage. The larger this ratio, the higher is the gain; the higher the gain, the more sensitive is the servo's output. If the gain of a servo is set too high, the output of the servo changes so rapidly it loses track of where the input order is, causing oscillation across the input signal. Oscillation (or hunting) is a very rapid back-and-forth movement of the output's load across the input signal, trying to "catch" the input. We can reduce the servo's tendency to oscillate by decreasing the gain of the amplifier. If we cut the gain down too far, the servo will overshoot the input signal because of insufficient sensitivity. To prevent both oscillation and overshooting, servos are provided with devices that directly and indirectly control the gain of amplifiers. Let us explore the meaning of these two terms before continuing the study of servo systems.

Oscillating

Oscillating, frequently called hunting, occurs when the output drives back and forth across the ordered position in short rapid swings, as though the output device were looking for a place to stop but cannot find it. Hunting is also characterized by its continuous action; it never stops or dies out; it can be very dangerous. If the output device oscillates at a rapid rate for a long time, it is possible to shake a gun mount or launcher to pieces and damage the power drives which control them and the weapons within the equipment.

Overshooting

Overshooting is similar to hunting, but the movement of the output load dies out after a short period of time. Overshooting starts out as large overtravels and progressively gets smaller until eventually the output shaft stops.

To get an idea of overshooting, we will look at how a servo reacts to a fixed input signal. Assume that the input shaft at the CX is stationary and at 0°, and the output shaft of the CT is at 10°. When the servo is energized, the servo motor will drive the load and try to reduce the error signal to zero when the desired position is reached, at which point the system is nulled and the error is zero. But, because the load and power drive have inertia and momentum, the output load continues to drive beyond the desired position. When the load crosses the desired position, an error is generated in the opposite direction which tends to reverse the direction of the output load. However, it takes the error signal some time to bring the output load to a stop. In other words, because there are components in a servo that do not react immediately to a signal, some time elapses before the output load can reverse its direction. During the response lag time period, the output load continues to move in the original direction, causing a larger error between the input and output. When the output load does stop, the error signal immediately starts to drive the output load back toward the desired ordered position. As the output load approaches the point of correspondence, it again has acquired enough speed in the reverse direction to again pass the ordered position. The result is a series of progressively smaller overtravels passed across the desired position until finally the output signal catches up with the ordered signal and the servo system stops.

Reducing Overshooting

To reduce overshooting and hunting, servos are provided with damping devices or circuits. They are frequently called stabilizing or antihunt circuits, and usually use some form of feedback. Feedback is the method by which a sample of the output is returned or fed back to the input to be added to or subtracted from the input, thereby changing and controlling the output.

The damping or stabilizing circuits (called a velocity system in the 5″/54 Mk 42 Mods 9 and 10 and Mk 45 gun mounts) in power servos are capable of acting as positive feedback devices to increase the gain of a servo amplifier when the error signal is increasing. It also acts as a negative feedback to reduce the gain of the amplifier when the error signal is decreasing. In this manner servos are prevented from overshooting and oscillating.

Three of the many methods of reducing overshooting and hunting in power drive servos will be explained in this chapter. One method, which is the technique of using a CT with a movable stator to prevent a gun or mount from overshooting a fixed order signal, is explained in chapter 8 of *GMG 3 & 2*, NAVEDTRA 10185-C1. The other methods we will cover are the use of tachometer generators and potentiometers for damping out oscillations and the integral control system, which increases the ability of a servo to follow slowly changing error signals and reduce velocity error.

Q9. What is the probable cause of oscillation across the input signal of a servo?

VELOCITY SYSTEM

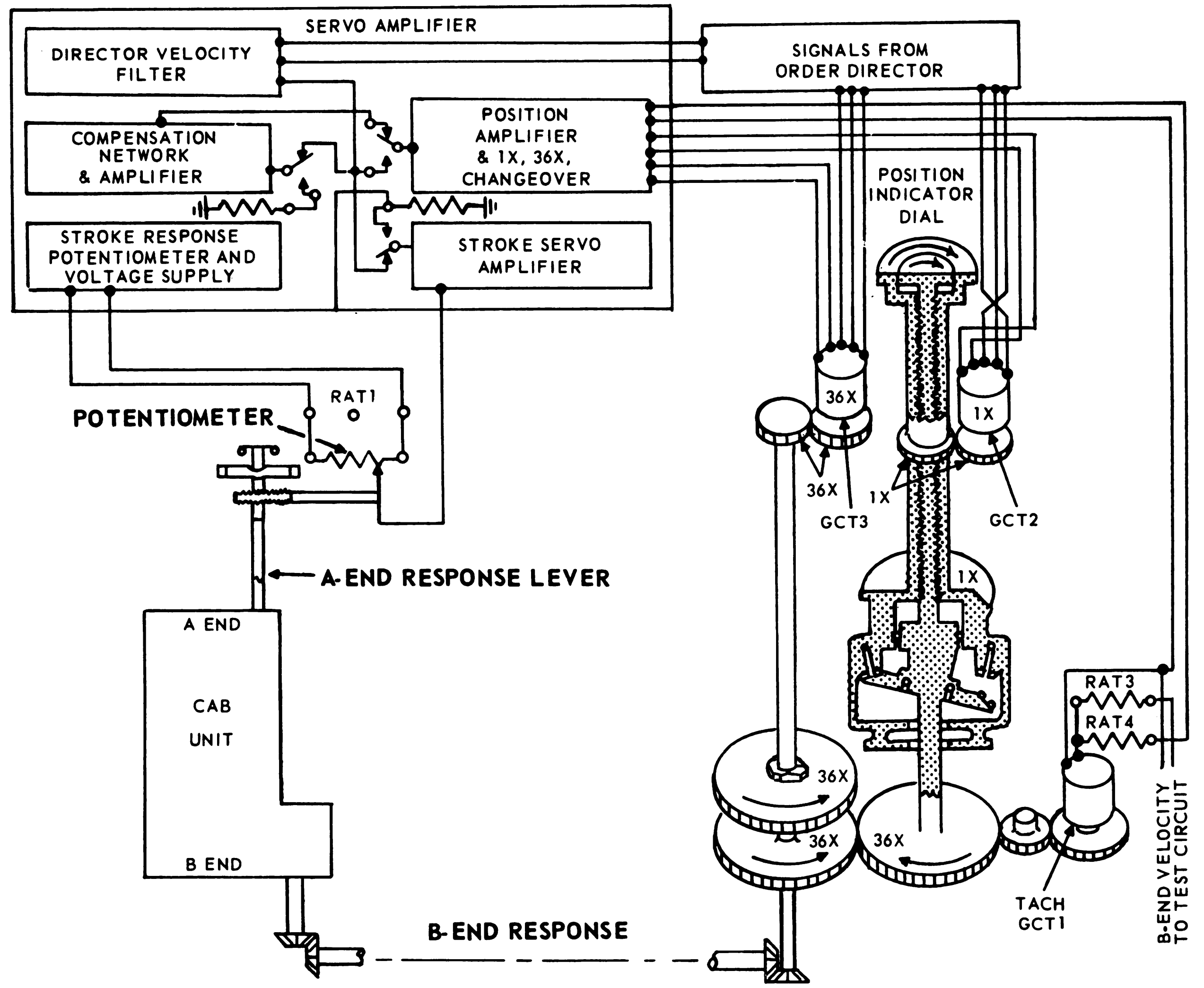
In the newer gun mounts (5″/54 Mk 42 Mods 9 and 10 and the 5″/54 Mk 45) the power drive servo system (figure 2-13) is divided into two subsystems called the position error detection system and the velocity system.

The position error detection system consists of the synchro system and the servo amplifier's synchro changeover circuits. By way of review, the position error detection system produces the error signal by comparing the order signal to mount position (B-end response).

The velocity system helps the power drive to follow constant velocity and roll signals smoothly. While the position error detection system is of primary importance when the power drive is synchronizing to a signal, the velocity system is primarily in control when the power drive is following a dynamic signal. Velocity inputs include a director velocity signal, a stroke response

ANSWER TO QUESTION Q8.

A8. Coarse.



53.262

Figure 2-13.—Servo system.

potentiometer signal (shown in figure 2-13 as RAT1), and a B-end response tachometer-generator signal (shown in figure 2-13 as GCT1).

The director velocity signal is a dc voltage proportional to the velocity of the director. With each degree per second of increasing order (right train or elevation), the director velocity signal is increased by a positive .5 volts, while with each degree per second of decreasing order (left train or depression), the director velocity signal is increased by a negative .5 volts.

When the A-end stroking piston moves the tilt plate, it also moves a response lever that is attached to a wiper arm on the stroke response potentiometer RAT1. Since the amount of A-end tilt is a close approximation of a gun mount's velocity, the potentiometer's output can be used as a mount velocity input to the servo amplifier. The output from RAT1 is negative for an increasing order and positive for a decreasing order (opposite of the director velocity signal). Thus, the output of RAT1 opposes the director velocity signal so that any difference between the ordered velocity signal and the actual velocity signal causes the gun mount power drive to accelerate or decelerate until the two velocity signals are equal. The following are three conditions that may exist when the gun is in motion:

1. When the gun is traveling at the proper speed in response to its order signal, no change in acceleration is required. Under this condition, the output of RAT1 is equal to the director

velocity signal but is opposite in polarity. Therefore, the sum of their output is zero and the error signal is neither increased nor decreased.

2. When the gun is moving slower than the ordered velocity, the output of RAT1 is less than the director velocity signal. Under this condition, the sum of their outputs is added to the error signal causing the gun to accelerate at a more rapid rate.

3. When the gun is moving faster than the ordered velocity, the output of RAT1 is more than the director velocity signal. Under this condition, the sum of their outputs is subtracted from the error signal, causing the gun to decelerate.

The tachometer generator GCT1 (fig. 2-13) is geared to B-end response and also measures gun velocity. Although the tachometer-generator signal indicates velocity, this signal is used to modify the error signal; it is not directly summed with the director velocity or the stroke response potentiometer velocity signals. As long as the gun is moving toward the order signal, the tachometer-generator signal opposes the error signal, producing 3 angular minutes of lag for each 20° per second of B-end velocity. This input's primary purpose is to reduce the tendency of the gun to overshoot the input order position when synchronizing with a slow moving or fixed input order signal. Under these circumstances, the effect of tachometer-generator output is to slow down the gun as it approaches the ordered position. If the gun does overshoot the ordered position, the tachometer-generator's output then aids the error signal to return the gun to its ordered position.

Figure 2-14 shows a functional diagram of the train servo amplifier for the 5"/54 Mk 42 Mods 9 and 10 and the 5"/54 Mk 45 gun mounts. Note that all three velocity inputs are applied to the filter circuit (PC6), but the B-end velocity signal is not applied to the error signal in this circuit board. It is applied to the error signal in the position amplifier (PC2).

Q10. What is the output of RAT1 if you have an increasing order?

INTEGRAL CONTROL

The purpose of the integrating system is to reduce error between actual gun order and gun position when the system is tracking in remote control. This can be accomplished either electrically or by hydraulic devices. We will explain the electrical method here and the hydraulic method in chapter 5.

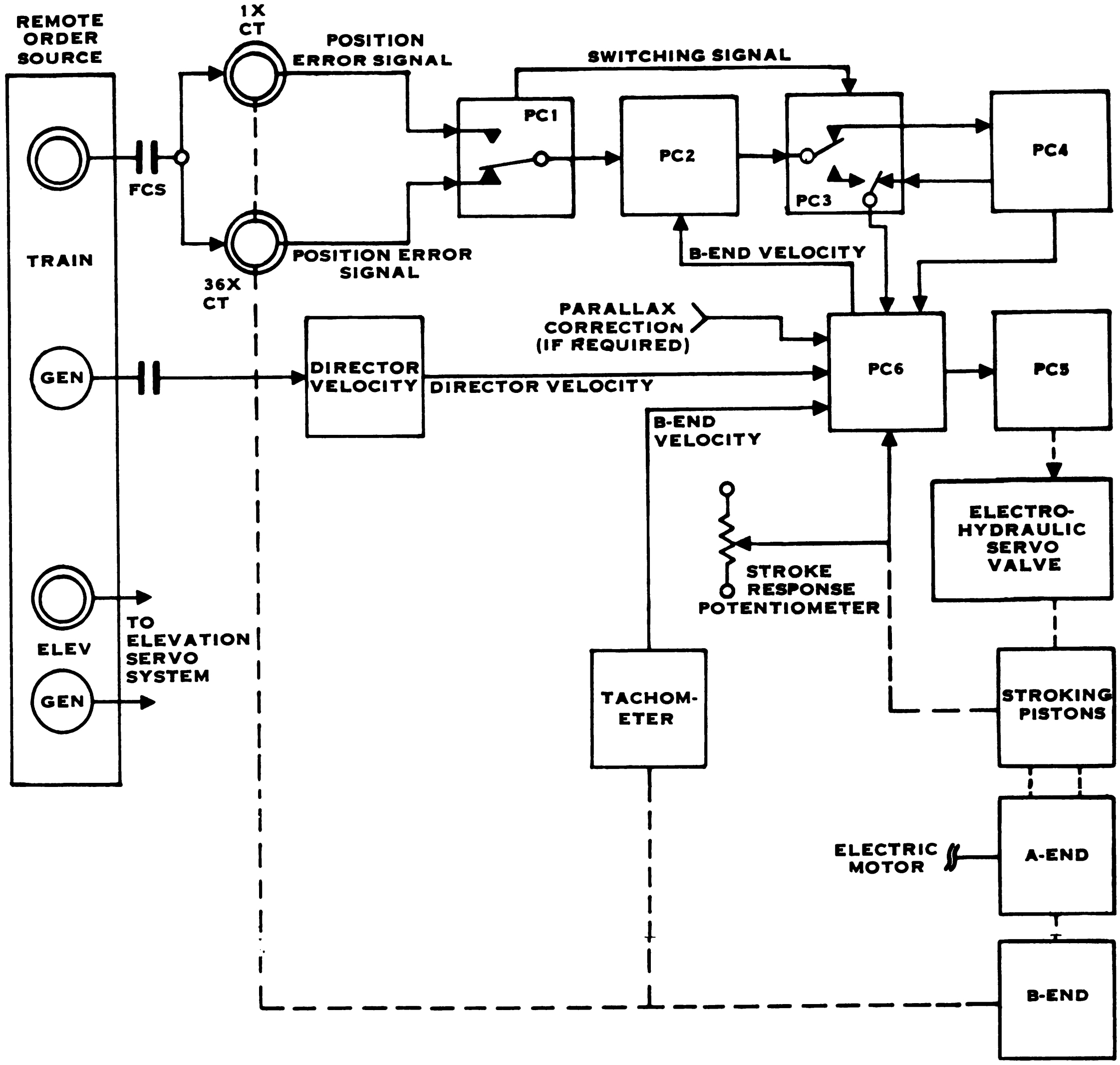
Power drives are required to follow constant velocity order signals. These signals occur, for example, when a gun director is following a target whose speed and range remain fairly constant. The input shaft to the gun mount's train order transmitter turns at a constant velocity (speed and direction) for a substantial percentage of time. Therefore, the power drive servo must respond to this type of input with as small an error as possible. But because there is always friction present, the output of the servo lags the position of the input shaft when both shafts are rotating at the same velocity. For example, if the input shaft is rotating at 10° per second, and the output shaft is moving at the same speed, but the angular position between them is a 1° difference, then a velocity error due to lagging exists.

To correct for velocity error, servos use integral control circuits. These circuits, like the output rate method, reduce velocity error to a minimum. The integral circuit modifies the error signal so that it is proportional to the length of time it exists, multiplied by the amplitude of the error signal. For example, suppose the output from a CX is 4 volts and it was produced by a constant error signal which lasted for 1 minute. If the same error signal lasted for only one-half minute, the output would be only 2 volts. You can see that if an error signal exists for a long time, its amplitude increases and an exaggerated error reducing action takes place; or, the servo will overcorrect the error because the speed of the output shaft increases more than it normally would, and thus catches up with the input shaft.

Figure 2-15 shows a simplified block diagram of an actual power drive servo. A simplified version of an integral control circuit is also illustrated. This circuit is located in the servo amplifier and is part of the compensating network.

ANSWER TO QUESTION Q9.

A9. The amplifier gain is set too high.



53.361

Figure 2-14.—Servo amplifier function diagram.

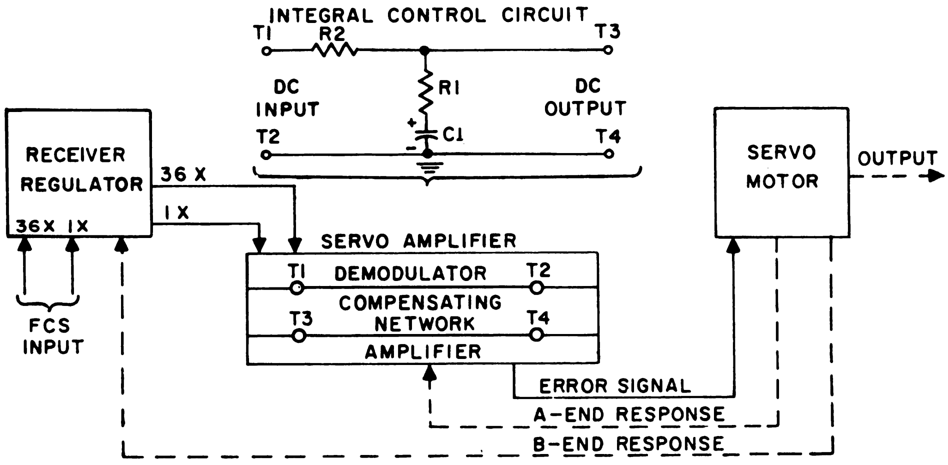


Figure 2-15.—Integral circuit.

Briefly, here is how the circuit works: The circuit is made up of two resistors and one capacitor. First the error signal is changed from ac to dc by a demodulator located in the servo amplifier. The components of the integral circuit are such that the capacitor's voltage does not change when the error voltage changes rapidly. Only the portion of the changing error signal developed across R1 is passed on to the amplifier section of the servo amplifier. If there is an error signal of longer duration, the capacitor will charge, increasing the voltage input to the amplifier. Therefore, this type of circuit is sensitive to constant or slowly changing error signals of the type you would expect from a velocity error. On the other hand, the integral control circuit ignores rapidly changing error signals. Remember, the higher the frequency of the voltage impressed across an R-C circuit, the more the capacitor acts like a short circuit. Rapidly fluctuating dc signals will be split between R1 and R2, because the capacitor acts like a short circuit or zero resistance. R2 is much larger than R1, so most of the fluctuating voltage is dropped across R2. A much smaller portion of the rapidly changing error signal appears across R1. Since R1 is in parallel with the input to the amplifier, only a small signal voltage is amplified.

Now look what happens in the circuit when the error signal is steady or changes slowly. This is the kind of signal you will get when a velocity error exists. Initially, all of a constant error voltage is distributed between R1 and R2, but the longer the error voltage is applied, the more C1 charges up. The increasing I-R drop across C1 adds to the drop across R1 and, since these two components are in parallel with the amplifier, their combined voltage will appear at the input terminals to the amplifier. In effect, the drive motor will overcorrect the error signal and the output will catch up with the input and correct for velocity error. In most synchro servo systems you will generally find that integral control circuits and devices operate with the fine error signal and not the coarse.

Q11. What is the purpose of an integrating system?

Q12. In the integral control circuit of a power drive servo, what changes the error signal from ac to dc?

SYNCHRO GEARING

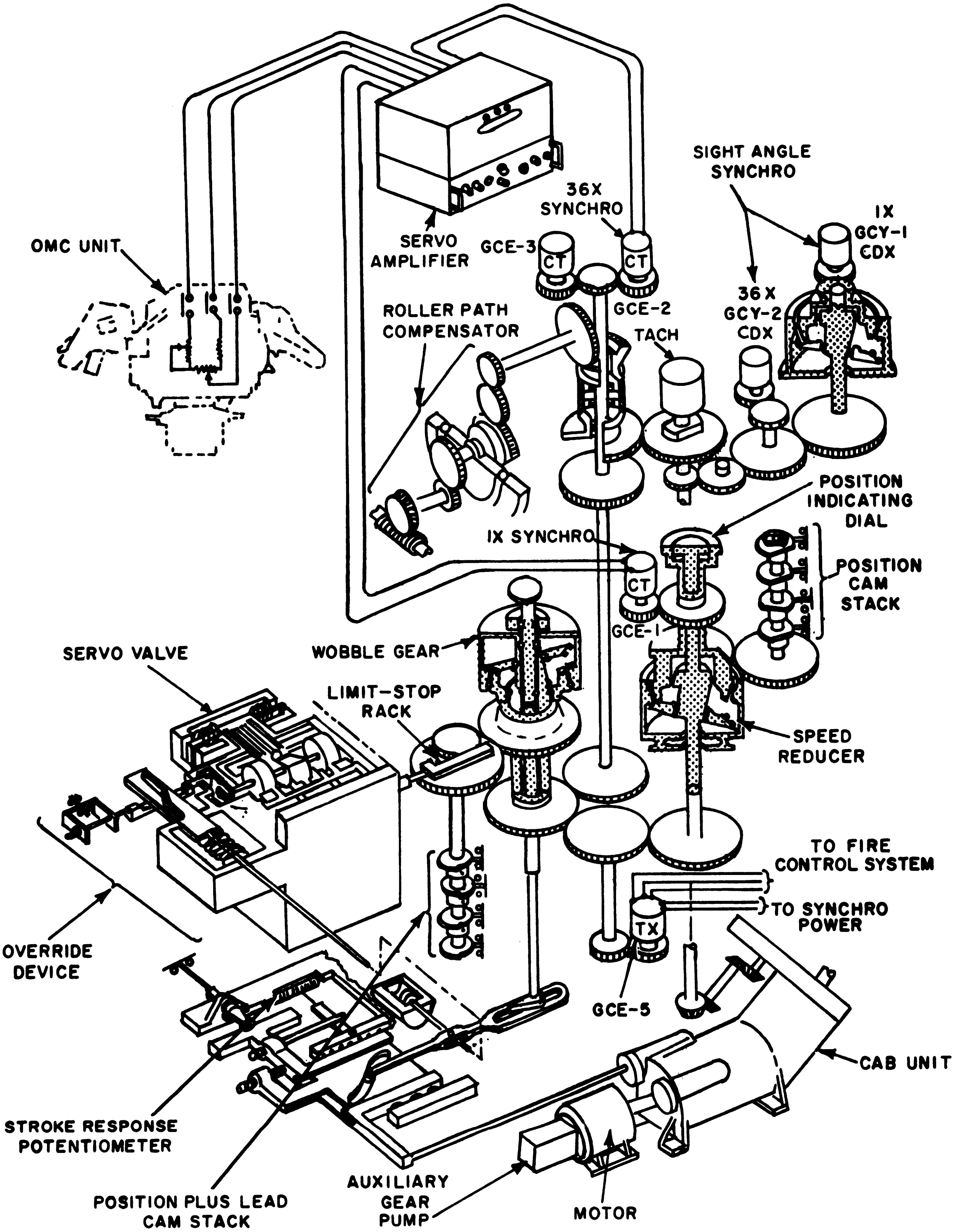
Synchro gearing is essential for continuously accurate operation of ordnance servo systems. They furnish gun mount position feedback information to the servo amplifier. They are also used to position limit stop cams, firing cutout mechanisms, and to furnish roller path tilt information which mechanically positions the rotors of elevation synchros to compensate for gun mount roller path tilt.

Figure 2-16 is a diagram of synchro gearing used with a modern gun system. In this type of synchro arrangement, all the rotors of the synchros are turned by B-end response. The outputs from the synchros are channeled to many different units of a servo system. Where more than one synchro is used in any one unit, only one synchro output is used at any one time. Synchro GCE-1 is for 1X operation and synchro GCE-2 is for 36X operation. Synchro GCE-3 is used for test purposes when in local control, and GCE-5 supplies position information to the fire control system. Synchros GCY-1 and GCY-2 provide sight angle correction information to a target acquisition sight. This sight is used for tracking targets when in local control.

In any synchro system it is important that the phase output of the 1X and 36X position synchros is the same. You should remember from your study of synchros that if you reverse the S1 and S3 leads to a synchro, you will change the phase of the synchro's output signal. Let's look at figure 2-13 again. You can see that the stator leads S1 and S3 to GCT-2 are reversed. When B-end response turns the rotor of the 36X synchro in a clockwise direction, it also turns the rotor of the 1X synchro in a counterclockwise direction. If the input to GCT-2 were a normal connection S1 to S1 and S3 to S3, the phase of its output signal would be opposite to that of the 36X synchro. Since both synchro outputs are fed into the servo amplifier to null out the position signal and to stop the gun when it reaches its ordered

ANSWER TO QUESTION Q10.

A10. Output is negative.



53.265

Figure 2-16.—Synchro gearing.

position, both output signals from the synchros must be the same. By reversing S1 and S3 leads to GCT-2, the output of both synchros will be in phase. If the S1 and S3 leads were not reversed, the synchros would fight each other and the gun would hunt across the ordered position and never settle down. It is very important to ensure that when a synchro is replaced in a system, it is connected according to up-to-date electrical prints. The phase shift was caused by mechanical synchro gearing and is compensated for electrically by reversing S1 and S3 leads to GCT-2.

Position Indicator

We stated that the purpose of GCE-5 in figure 2-16 was to send to one or more fire control systems the latest position of a gun mount. This information can be useful to a ship's weapons officer when a weapon system has many gun mounts, launchers, and fire control systems. A TX can be used with many TRs (fig. 2-2) located in different fire control stations to indicate mount position. A TX and TR synchro setup can also be used for testing purposes.

Optical Servo System

A target acquisition sight is used with a sight telescope in modern gun systems to locate and track low speed or surface targets during gun mount local control operation. These sights use a servo system which functions to continuously and accurately position the rotatable optical elements in accordance with synchro orders received from a fire control system.

The servo consists of two separate mechanisms—one for elevation and one for traverse. Each mechanism has a 1X and 36X CT, a servomotor generator, a gear train, and a servo amplifier. The operation of the servo system shown in figure 2-17 is as follows: To correct the telescope for sight angle, an electrical input from a fire control system is applied to the sight angle synchros GCY-1 and GCY-2 (fig. 2-16), located in the elevation receiver regulator. The sight angle synchros combine this sight angle input and the elevation B-end response input into a single output signal and direct it to the telescope's elevation synchros. The sight angle synchros GCY-1 and GCY-2 are CDX types of synchros and function to either add or subtract its two input signals. Their output signals are fed to two CTs located in the telescope's servo chamber in the form of coarse and fine synchro signals. The CTs also receive a servo response (feedback) signal representing the actual position of the optical elements. On the basis of the two signals, the CTs act as error detectors and generate an ac error signal. The error signal is fed to a limiter circuit (synchro changeover circuit) which selects either a fine or a coarse signal. The error signal is then fed into a servo amplifier whose output controls a servomotor. The servomotor drives the optical elements to the ordered position. The signal is canceled out by the optical elements' response to the controlling CT.

Again we have a basic synchro system designed not to move a large gun mount but only position a small mirror. As you can see, servo systems are used in many different ways in ordnance equipment. The important thing to remember about an ordnance servo system is that it must continuously and accurately position its load whether it is a gun mount, turret, missile launcher, or a small optical mirror.

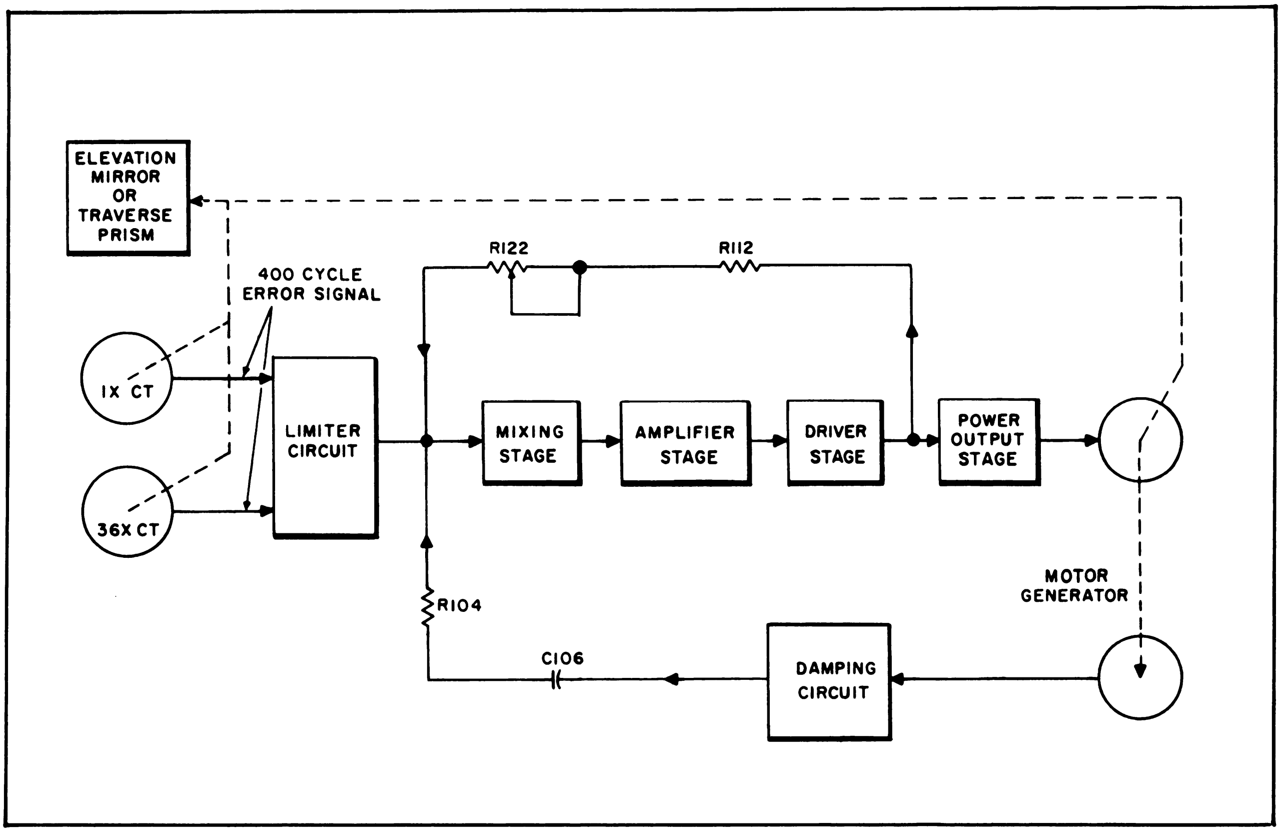
Servo System Components

In the servo system shown in figure 2-16, we used three different types of synchros. The control transformers (CTs) were used as error detectors, the differential transmitters (CDXs) were used as

ANSWERS TO QUESTIONS Q11 AND Q12.

A11. To reduce error between the actual order and gun position when the system is tracking in remote control.

A12. Demodulator located in the servo amplifier.



53.266

Figure 2-17.—Optical servo system.

inputs to an optical servo system (one servo controlling another), and a torque transmitter (TX) was used to furnish actual gun mount position to a fire control system. The types of synchros used in a servo system are determined by its intended purpose. The servo's purpose also determines the output device used to control the servo's load. The servo's load is driven by the output device (usually called a servomotor) whose function is to supply torque, power, and the dynamic characteristics required to position the servo's load. The types of servomotors used with ordnance servo systems are electric motors, amplidyne motor-generators, or electric-hydraulic units (A-end/B-end combinations). These systems are described briefly in subsequent paragraphs.

Q13. When there is more than one synchro used in a servo system, how many outputs can be used at any one time?

Q14. What is the primary purpose of a target acquisition sight in gun systems?

AMPLIDYNE SERVO SYSTEMS

Heavy guns can be trained and elevated by direct handwheel action through the gearing system. Naturally, this relatively slow and difficult method is not normally used in battle, but it is necessary for certain adjustment or maintenance operations. To move the guns quickly, easily, and accurately in response to a signal, either an amplidyne or an electric-hydraulic servo system can be used. For light to moderately heavy loads—such as missile launchers and 3-inch gun mounts—amplidyne power drives are reliable and accurate. Also, they are easier to maintain than the electric-hydraulic system designed for heavier loads.

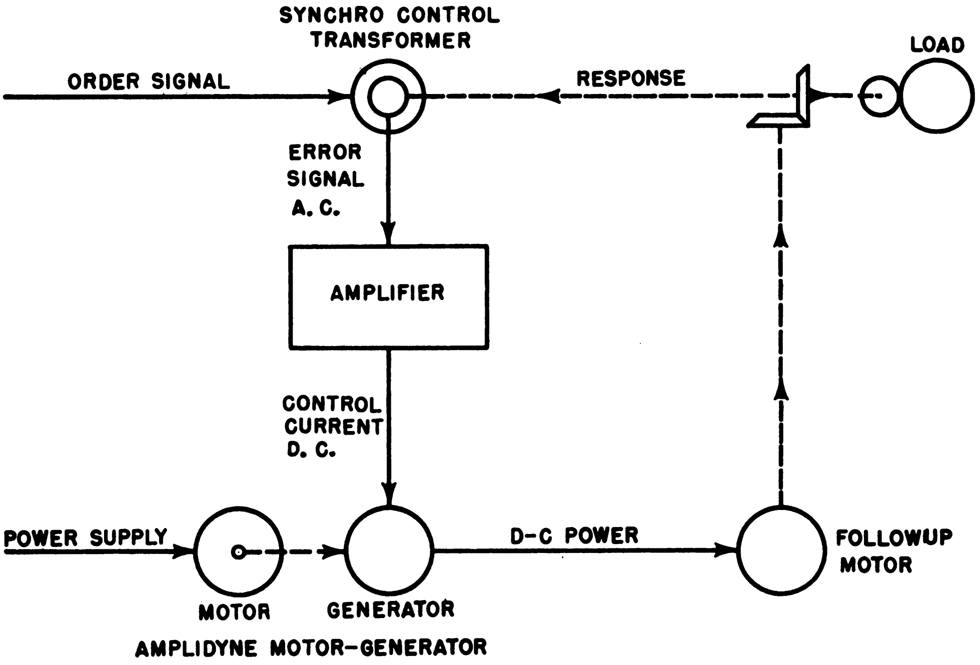
In figure 2-18, an amplidyne followup system has been reduced to its bare essentials—a pair of CTs (illustrated as a single unit for the sake of simplicity), an amplifier, an amplidyne motor-generator, and a followup dc servomotor.

In the CT, the input to the stator is an order signal from a remote CX. The position of the rotor represents the response of the load. The output of the CT is the ac error signal. Actually, two CTs—a coarse and a fine one—are used. When the gun is within 3° of its ordered position, the fine synchro is automatically connected to control the system replacing the coarse synchro.

The control amplifier uses gas-filled electron tubes (called thyratons) for two purposes. First, the thyratons rectify the ac input; that is, they convert this input to a dc output whose magnitude and direction measure the amount and direction of error. Second, they amplify the signal and produce two dc outputs that are fed to the control field windings in the amplidyne generator, as explained in the following paragraphs.

The amplidyne generator is a special adaptation of one type of ordinary commercial dc generator. Such a generator has a wire-wound rotor that turns within the field of an electromagnet on the stator. Figure 2-19, view A, shows a conventionally connected dc field schematic. Excitation power to the field is 100 watts dc to produce field FC. The arrow shows the direction of this field.

The larger circle between the two poles represents the rotating armature, which is driven



110.25

Figure 2-18.—Essentials of an amplidyne followup system.

ANSWERS TO QUESTIONS Q13 AND Q14.

A13. One.

A14. To locate and track low speed or surface targets during local control operation.

at constant speed by a motor (not illustrated). Rotation in field FC induces an ac voltage in the armature winding.

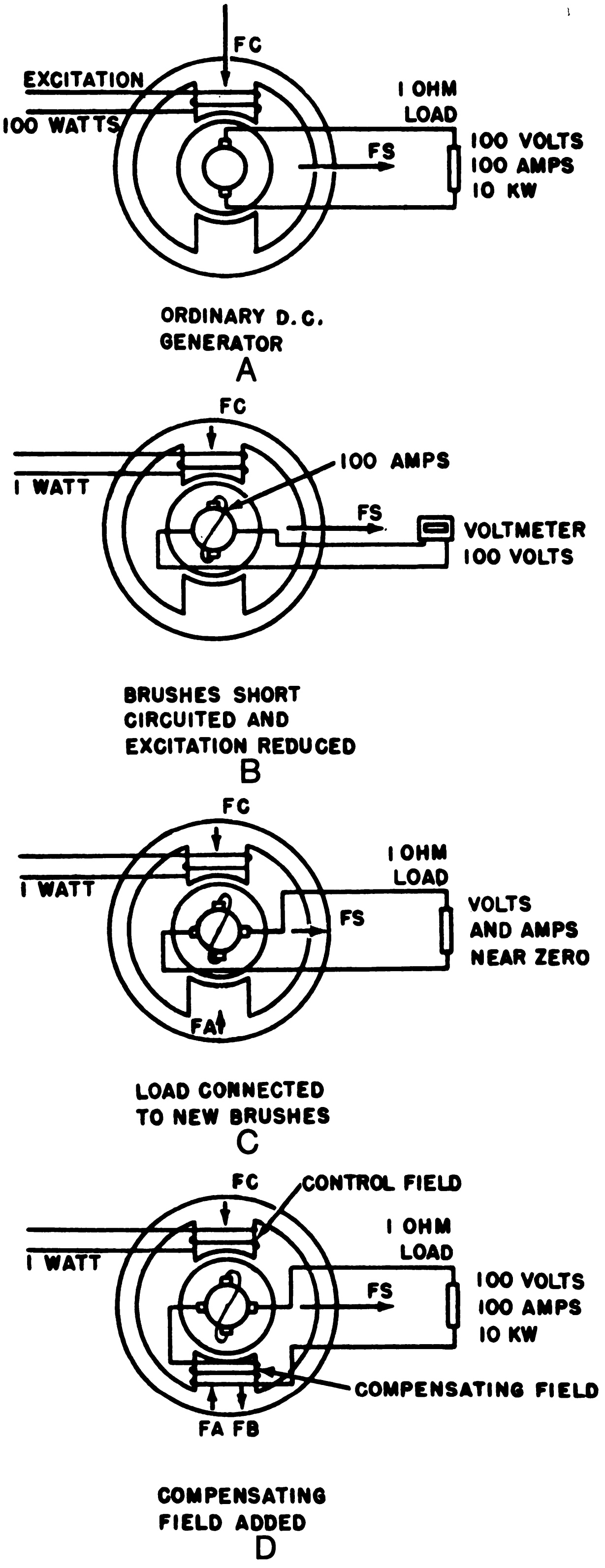
The small inner circle represents the commutator. In the conventional dc generator, the commutator connects the armature output to an external dc load circuit by contact with a pair of stationary carbon brushes, 180° apart. The generated (or load) current, as it passes through the armature winding, creates its own magnetic field (FS). This field, called armature reaction, serves no useful purpose.

Normally, other things being equal, the power output of the generator will be proportional to the excitation power. This generator is assumed to be a 10-kW machine (10,000 watts output), and the excitation required is about 100 watts. The "amplification," therefore, is 100 to 1.

The first step in transforming this ordinary dc generator into an amplidyne generator is to short circuit the two brushes as shown in figure 2-19, view B. Now an immense armature current will flow, but if excitation is cut down to about 1 watt, FC is reduced, and 100 amperes again flow through the armature, producing the same armature reaction, FS, as before.

The next step is to add a second pair of brushes at right angles to the short-circuited pair, and to connect the load circuit over these brushes, as shown in figure 2-19, view C. Now, however, the output voltage becomes very low, because the new output circuit has created its own armature reaction, FZ, which opposes FC and greatly reduces its effect.

Now put a compensating winding, so connected that armature current passes through it on the second pole of the electromagnet, as in figure 2-19, view D. This winding produces field FB to nullify FA and thereby allows FC to become fully effective again. The ordinary dc generator has now become a basic amplidyne generator in which full-load output is developed with 1-watt excitation ("amplification" of 10,000 to 1). Thus it can operate on very low excitation (e.g., the output of the amplifier in figure 2-18) and still furnish enough power to drive a large servomotor (the followup motor in figure 2-18).



ORDINARY D.C. GENERATOR
A

BRUSHES SHORT CIRCUITED AND EXCITATION REDUCED
B

LOAD CONNECTED TO NEW BRUSHES
C

COMPENSATING FIELD ADDED
D

110.26

Figure 2-19.—The development of an amplidyne generator.

The amplidyne generator must control the direction of its followup motor's rotation, as well as its torque. To accomplish this, the amplidyne generator has two control fields instead of the one shown in figure 2-19, view D. One of these is wound in the opposite direction to the other. The direction of FC and of generator output depends on which receives more current from the amplifier. If the amplifier supplies equal currents to both control windings, generator output is zero and the followup motor stands still. When control winding currents differ, the followup motor will develop a torque whose direction depends on which current is greater, and whose magnitude depends on the amount of the difference.

The followup motor operates in a slave-to-master relationship with the amplidyne generator. Under a given load, its speed and direction of turning depend on the amount and direction of its dc input from the generator. Its output is mechanical power to drive the load in the right direction until the error signal has been reduced to zero.

Q15. What type of control is necessary for certain adjustment or maintenance operations of heavy guns?

ELECTRIC-HYDRAULIC SERVO SYSTEMS

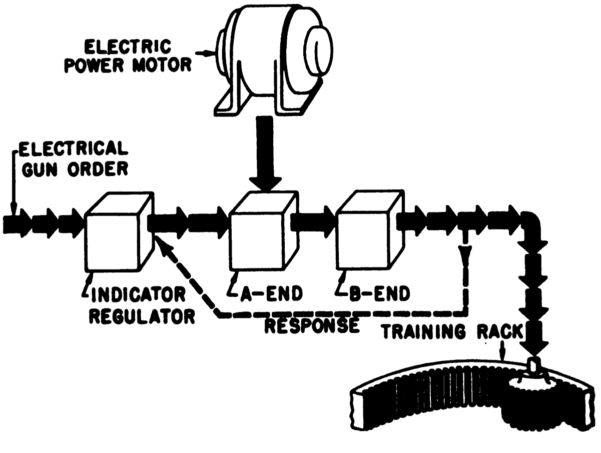
The electric-hydraulic power drive was developed to perform heavy gun laying. At this stage of your naval career, you should be familiar with at least the basic operating principles of this type of drive—so, only a brief rundown will be given here. More detailed information on both amplidyne and electric-hydraulic power drives and control equipment will be presented in chapters to follow in this manual.

The order signals to an electric-hydraulic system normally originate at a remote station. They enter through a complex unit sometimes called an indicator-receiver-regulator, but more often shortened to indicator-regulator. This unit contains synchros and related devices for (1) receiving the order signal and the response, (2) computing the error signal, (3) amplifying the error signal, and (4) transmitting this signal to the hydraulic system through an arrangement of valves and pistons.

A conventional ac electric polyphase induction power motor, connected to the ship's regular power supply through a system of reduction gears, drives the hydraulic pump (A-end) at virtually constant speed, regardless of A-end output.

The output of the A-end is hydraulic pressure that drives the B-end. The output of the B-end mechanically drives the gun through a shaft and pinion. The input the B-end receives from the A-end determines the direction, speed, and duration of its output. In turn, the direction and amount of the gun's movement in train or elevation depend on the output of the B-end to the gun's gearing system.

Figure 2-20 shows the sequence of operations when the mount is trained in automatic control. (Compare this figure with figure 2-18 showing the essentials of an amplidyne system.) The gun order signal is compared with the response, and the error signal is generated and amplified. The amplified error signal positions the A-end socket ring, thus regulating A-end output. A-end output drives the B-end which, in turn, drives the training pinion. Mechanical response from the gearing is an input to the indicator-regulator where, with the order signal it combines to generate the error signal. As gun position approaches synchronism



110.27

Figure 2-20.—A train power drive in automatic control.

with the gun order signal, the error signal decreases, becoming zero or null when gun position equals gun order.

Guns, however, are far from being the only ordnance equipment that must be moved smoothly, rapidly, and accurately in response to incoming signals. Missile launchers and certain types of projectors have control arrangements similar, in many features, to those used with conventional gun mounts. By their nature, systems designed to launch guided missiles must be capable of operating even more swiftly, accurately, and dependably than any except the newest gun systems. As in conventional guns, the designer's choice of amplidyne or electric-hydraulic drive is governed largely by the weight and other physical features of the given system.

Q16. What determines the direction and amount of movement in train or elevation of a gun mount?

SERVO SYSTEM RATINGS

Servo systems are qualitatively rated in accordance with the following characteristics:

STATIC ERROR is the angular lag between the input and output under static conditions. A low figure is desirable.

STATIC ERROR UNDER LOAD is the angular lag produced between input and output by applying a specific torque to the output. A low figure is desirable.

VELOCITY FIGURE OF MERIT is the figure obtained by dividing the velocity of the output (expressed in degrees per second), by the angular lag between output and input (expressed in degrees), when the system is moving its load at a constant speed. It indicates how quickly the system responds to a constant input. A high figure is desirable.

DAMPING CONSTANT is related to the transient response of a servo. An overdamped servo is sluggish and usually responds to a change without overshooting. A slightly underdamped servo usually gives a quick response to practically no oscillation. A greatly underdamped servo usually will overshoot badly and oscillate for some time after a change in position is called for.

ACCELERATION FIGURE OF MERIT is the ratio between a constant acceleration of the system, expressed in degrees per second, and the angular lag between output and input, expressed in degrees. A high figure indicates system ability to follow an increasing or decreasing input accurately and rapidly.

MAINTENANCE

Synchro units require careful handling at all times. Never force a synchro unit into place; never drill holes in its frame; never use pliers on the threaded shaft; and never use force to mount a gear or dial on its shaft.

Synchros are no longer considered as repairable items. Replaced synchros should be disposed of in accordance with current instructions. Never take a unit apart or try to lubricate it unless it is an emergency and no replacement unit is available.

Before testing a new installation and before hunting trouble in an existing system, be certain all units are zeroed. Also, be sure the device's mechanical position corresponding to electrical zero position is known before trying to zero the synchros. The mechanical reference position corresponding to electrical zero varies; therefore, it is suggested that the instruction books and other pertinent information be carefully read before attempting to zero a particular synchro system.

Zeroing Synchros

Synchros must work together properly in a system. Therefore, it is essential that they be correctly connected and aligned in respect to each other, and to the other devices, such as directors and guns, with which they are used. The best of ordnance equipment would be ineffective if the synchros in the data transmission circuits were misaligned electrically or mechanically. Since synchros are the heart of the transmission system, it stands to reason that they must be properly connected and aligned before any satisfactory shooting can be expected.

Electrical zero is the reference point for alignment of all synchro units. The mechanical reference point for the units connected to the synchros depends upon the particular application of the synchro system. As a GM on board ship, your primary concern with mechanical reference point will be the centerline of the ship for gun train and the standard reference plane for gun elevation. Remember that whatever the system, the electrical and mechanical reference points must be aligned with each other.

There are two ways in which this alignment can be accomplished. The most difficult way is to have two individuals, one at the transmitter and one at the receiver or control transformer, adjust the synchros while talking over sound-powered telephones or some other communication device. The better way is to align all the synchros to electrical zero. Units may be zeroed individually, and only one person is required to do the work. Another advantage of using electrical zero is that trouble in the system always shows up in the same way. For example, in a properly zeroed TX-TR system, a short circuit from S2 to S3 causes all receiver dials to stop at 60° or 240°.

In summary, zeroing a synchro means adjusting it mechanically so it will work properly in a system in which all other synchros are zeroed. This mechanical adjustment is accomplished normally by physically turning the synchro rotor or stator. The methods for zeroing synchros are explained in *GMG 3 & 2*, NAVEDTRA 10185-C1, and MIL-HDBK 225(AS).

Troubleshooting Synchro Systems

Shipboard synchro troubleshooting is limited to determining whether the trouble is in the synchro or in the system connections. If something is wrong with the unit, replace it. Generally, two categories of trouble occur in synchro systems: (1) those likely to occur in new installations, and (2) those likely to occur after the system has been in service awhile.

New Installations

In a newly installed system, the trouble probably is the result of improper zeroing or wrong connections. Make certain all units are zeroed correctly: then check the wiring. Do not trust the color coding of the wires; check them out with an ohmmeter. A major source of trouble is improper excitation. Remember, the entire system must be energized from the same power source for proper operation.

Established Installations

In systems which have been working, the most common trouble sources are as follows:

1. Switches—Shorts, opens, grounds, corrosion, wrong connections.
2. Nearby equipment—Water or oil leaking into the synchro from other devices. If this is the trouble, correct it before installing a new synchro.
3. Terminal boards—Loose lugs, frayed wires, corrosion, and wrong connections.
4. Zeroing—Units improperly zeroed.

Wrong connections and improper zeroing in any system are usually the result of careless work or inadequate information. Do not rely on memory when removing or installing units. Refer to the applicable instruction book or standard plan. Tag unmarked leads or make a record of the connections. Someone else may need the information.

Q17. What should you ALWAYS do before attempting to zero a particular synchro system?

Q18. What is the reference point for all synchro units?

Q19. In troubleshooting synchros, what is the general rule you should follow if something is wrong with the synchro unit itself?

ANSWERS TO QUESTIONS Q15 AND Q16.

A15. Direct handwheel.

A16. The output of the B-end.

SUMMARY

This chapter provides only basic information on synchros and servo systems as they relate to the operation of ordnance equipment. It is not within the scope of this manual to cover the intricate internals of these systems, but to examine the various types, arrangements, and interconnections of the components to achieve the desired output function. In this regard, we have covered the classifications, characteristics, and basic principles of several types of synchros required to form a servo system. We have also addressed the many factors that affect the accuracy of these systems. Alignment, maintenance, and troubleshooting procedures were also discussed.

Experience has shown this writer that there is a general lack of understanding on the part of many gunners of the required interconnection arrangements and operating characteristics of synchros used to convert mechanical signals to electrical signals and vice versa to achieve the purpose of a servo system (position a sensitive indicator, control a motor used to move gun mounts, etc.). This chapter outlines many of these arrangements.

For more detail on the functioning, maintenance, and troubleshooting of synchros and servo systems, it is suggested that you consider the reference material listed at the end of this chapter. The gunner that researches references for further refinement of a particular subject will surely become the expert in that area.

REFERENCES

The following reference materials were used to develop the information presented in this chapter.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

Navy Electricity and Electronics Training Series (NEETS), Module 15, *Principles of Synchros, Servos, and Gyros*, NAVEDTRA 172-15-00-85, Naval Education and Training Program Development Center, Pensacola, Fla., 1985.

United States Navy Synchros, Description and Operation Handbook, MIL-HDBK-225(AS), Department of the Navy, Washington, D.C., 1968.

ANSWERS TO QUESTIONS Q17 THROUGH Q19.

A17. Ensure that you have carefully read the instruction books and other pertinent information for that system.

A18. Electrical zero.

A19. Replace the unit.

CHAPTER 3

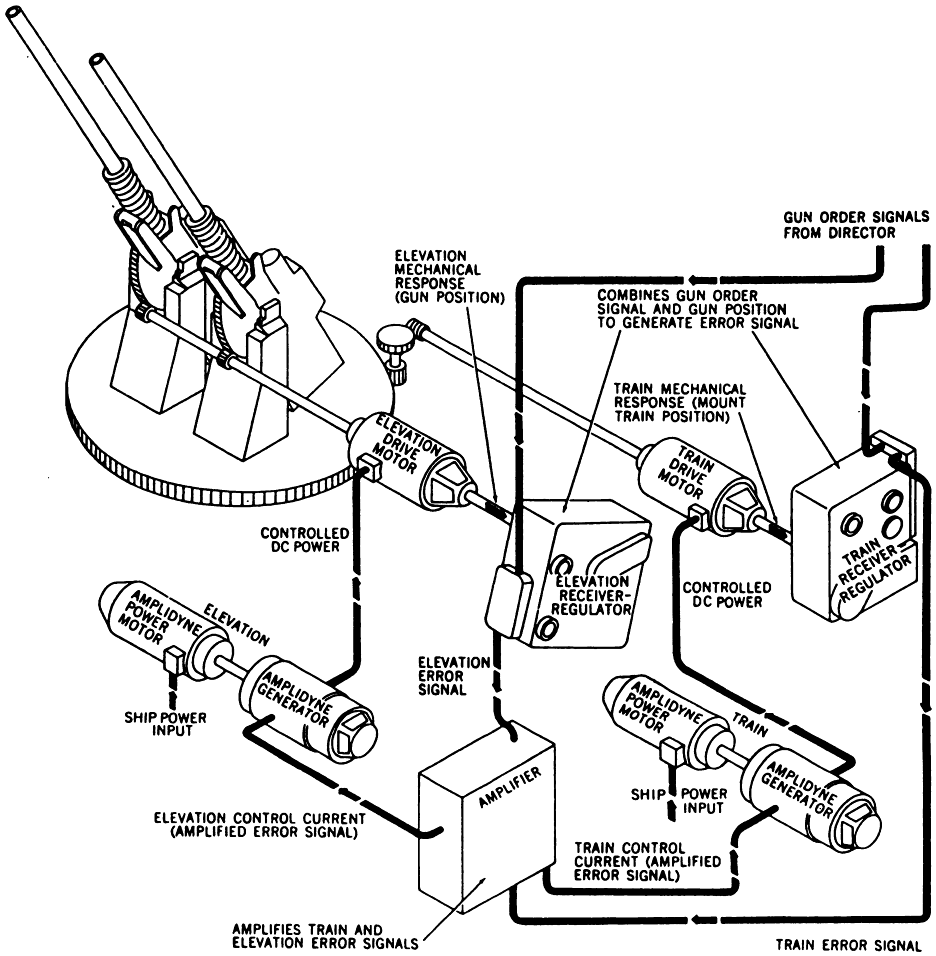
AMPLIDYNE POWER DRIVES

The purpose of any power drive is to provide the controlled power required to move a prescribed load to a designated position. Power is fairly easy to obtain, but to be effective, it has to be controlled. That is, the correct amount of power must be applied, in the right direction, for the proper length of time, to move the load to a designated position.

An amplidyne power drive consists of a special-purpose ac generator coupled to a dc motor to supply large dc currents required to drive heavy physical loads.

Think of the problems the requirements of a gun mount power drive present. The load weighs several tons; the accuracy demanded is measured in minutes of arc; the signals used to control the drive are bidirectional at variable speeds; and the response to a signal has to be almost instantaneous. The equipment has to be rugged to withstand gun shock and weather, yet reliable to operate with a minimum of maintenance. The amplidyne power drive meets all of these requirements.

The Mk 35 power drive (fig. 3-1) is of the amplidyne type and provides the controlled power


GUN ORDER SIGNALS FROM DIRECTOR
ELEVATION MECHANICAL RESPONSE (GUN POSITION)
COMBINES GUN ORDER SIGNAL AND GUN POSITION TO GENERATE ERROR SIGNAL
TRAIN MECHANICAL RESPONSE (MOUNT TRAIN POSITION)
ELEVATION DRIVE MOTOR
TRAIN DRIVE MOTOR
CONTROLLED DC POWER
ELEVATION RECEIVER-REGULATOR
CONTROLLED DC POWER
TRAIN RECEIVER-REGULATOR
AMPLIDYNE POWER MOTOR
ELEVATION
AMPLIDYNE GENERATOR
ELEVATION ERROR SIGNAL
SHIP POWER INPUT
AMPLIDYNE POWER MOTOR
TRAIN
AMPLIDYNE GENERATOR
SHIP POWER INPUT
AMPLIFIER
ELEVATION CONTROL CURRENT (AMPLIFIED ERROR SIGNAL)
TRAIN CONTROL CURRENT (AMPLIFIED ERROR SIGNAL)
AMPLIFIES TRAIN AND ELEVATION ERROR SIGNALS
TRAIN ERROR SIGNAL

53.37

Figure 3-1.—Amplidyne power drive used with the 3″/50 twin gun mount.

required to train and elevate a 3"/50 gun mount.

We will explain how the Mk 35 power drive controls the movements of a 3"/50 gun mount. You will also find that there is some similarity between the electric drive and the hydraulic drive. A different type of energy is used in each of these systems, but the same purpose is accomplished. You are probably more familiar with hydraulic drives; the similarity will be pointed out when necessary.

BASIC FUNCTION OF THE POWER DRIVE

The 3"/50 equipment contains two separate, but almost identical, power drives. One of them controls the gun mount's/missile launcher's elevation angle, and the other controls its train angle. The power drives are operated in one of two modes—automatic/remote or local. In either mode, both drives are operated simultaneously; one cannot be placed in automatic and the other in local.

There is no manual operation; however, handcranks are provided for use in stowing and maintenance. The handcranks are not permanently installed, but are stowed on the mount.

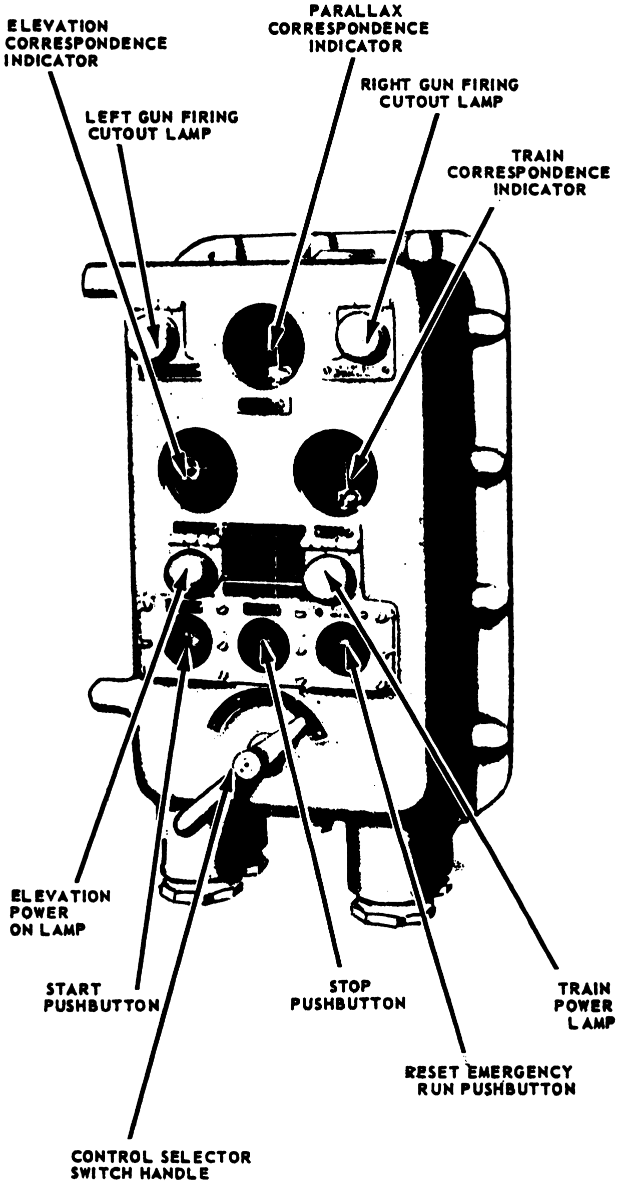
AUTOMATIC CONTROL

The Mk 35 power drive and, hence, its armament, are normally controlled automatically by train and elevation order voltages generated by a remote director or computer (fig. 3-1). Position order voltages are applied to synchro control transformers in receiver-regulators located on the armament. The synchros compare the actual position of the armament with the ordered position. If the actual position of the armament differs from the ordered position, the synchros develop ac error voltages. These voltages are transmitted to the amplifier where they are amplified and rectified. The polarity of the rectified voltage is determined by the phase angle of the error, while the amplitude of the voltage is determined by the amount of error. This dc error voltage is transmitted to the amplidyne generator that responds by producing train and elevation control power. This power is applied to the armament's train and elevation drive motors, which move to the ordered position. This action returns the train and elevation error voltages to zero by repositioning the synchro control transformers in the receiver-regulators. The armament, therefore, comes to rest at the ordered position.

LOCAL CONTROL

If the automatic mode of control is disabled in the gun mount, the power drive can be controlled locally by the train and elevation order voltages generated at either of the two one-man control (OMC) stations. The local control stations are called local-surface and local-AA. (The local-surface station is shown in figure 3-1).

A Mk 62 control panel is located at the local-surface station (fig. 3-2). It is at this panel that


ELEVATION CORRESPONDENCE INDICATOR
PARALLAX CORRESPONDENCE INDICATOR
RIGHT GUN FIRING CUTOUT LAMP
LEFT GUN FIRING CUTOUT LAMP
TRAIN CORRESPONDENCE INDICATOR
ELEVATION POWER ON LAMP
START PUSHBUTTON
STOP PUSHBUTTON
TRAIN POWER LAMP
RESET EMERGENCY RUN PUSHBUTTON
CONTROL SELECTOR SWITCH HANDLE

53.38

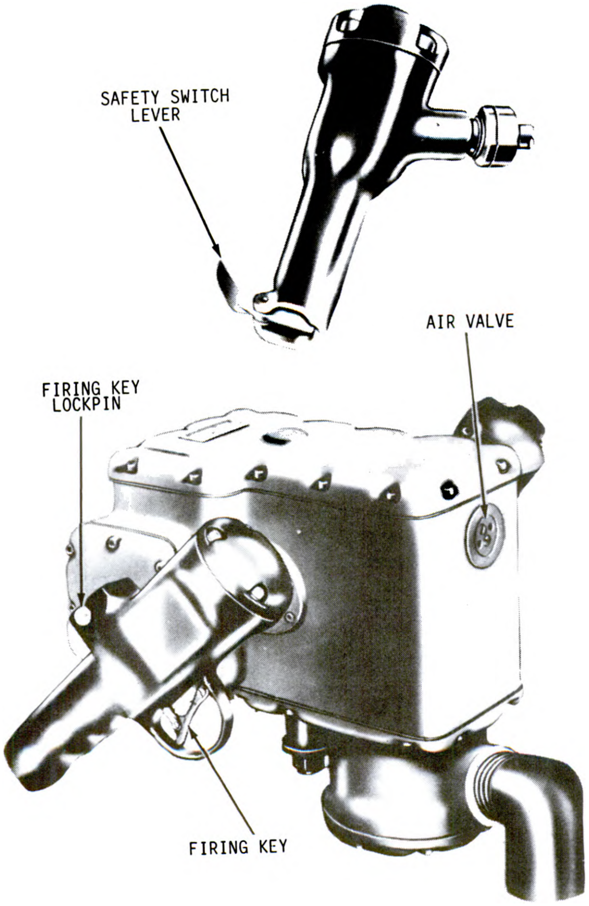
Figure 3-2.—Mk 62 control panel of local-surface station.

the selection of which controlling station (local-surface, local-AA, or the director) is made. Only one station at a time can control the gun mount.

GUN CONTROL STATION

The local-surface or local-AA operator moves the handles of the OMC station (fig. 3-3) to develop gun order voltages. To change elevation, the handles are tilted about their mounting axis. The direction in which the upper ends of the handles are moved is the direction in which the gun will move. To change gun train, the entire OMC unit is displaced about its mounting axis. In both train and elevation, the degree of displacement or tilt governs the speed at which the gun moves. When the safety switch on the left-hand handle is closed, it energizes the local circuits.

Control by the two local stations is functionally the same. Let us use local-surface and elevation drive to see how the local control systems function.



53.39

Figure 3-3.—One-man control unit.

As the handles are tilted, the OMC unit generates a speed order voltage and applies it to the amplifier, where it produces a dc elevation control current. This current energizes the control field of the amplidyne generator, thereby causing the amplidyne to generate dc power for the drive motor. The drive motor starts to move the guns, and mechanical response to the receiver-regulator drives a tachometer generator. The tachometer generates a gun speed voltage and applies it to the amplifier, where it opposes the speed order voltage. The amplitude of the gun speed voltage increases as the speed of the drive motor increases.

The speed of the drive motor will continue to increase until the tachometer voltage reaches a certain level. At this point no increase in mount speed is possible until the operator moves the OMC farther off center.

When the operator returns the control unit to neutral, the gun order signal is removed. Because of inertia, the mount tends to continue driving. The tachometer, still generating voltage, continues to apply feedback to the amplifier in opposition to the original signal; the feedback signal causes the mount to slow down. As the mount slows down, the tachometer feedback (which is dependent on mount speed) decreases. Thus, the tachometer generator voltage brings the mount to a smooth stop.

Q1. What is the purpose of the handcranks on the 3"/50 gun mount?

Q2. What governs the speed of train and elevation in local control?

AMPLIDYNE GENERATOR

The amplidyne generator is the heart of the Mk 35 power drive. This dc generator is the component that amplifies a low-power electrical signal into a signal strong enough to drive a gun mount. The output of the dc generator is the input to the drive motor. The direction of gun mount movement is determined by the polarity of the generator output.

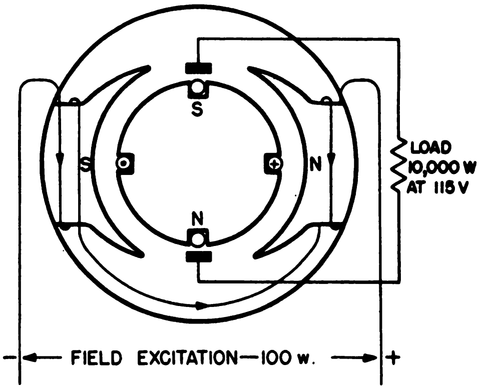
(Now is the time to review the Navy Electricity and Electronics Training Series (NEETS), Module 5, *Introduction to Generators and Motors*, NAVEDTRA 172-05-00-79, if the principles of dc generators are hazy in your mind.)

Any dc generator can be used as an electric power amplifier. Its amplification factor is approximately 100. This means that if you apply 1 watt to its excitation field, the generator will deliver approximately 100 watts to the load. Amplification occurs when the generator rotor cuts the magnetic field supplied by the excitation current. Thus the mechanical movement of the rotor is the source of the output power. (Remember that a generator converts mechanical energy to electrical energy.)

Let us look at an amplidyne generator, part by part, to see how it can have an amplification factor of 10,000 when a normal generator has an amplification of only 100. An ordinary dc generator (fig. 3-4) depicts a separately excited generator with a 100-watt external supply. This 100-watt input will be amplified by 100 (the amplification factor of a dc generator) to produce a peak output of 10,000 watts. The field windings set up a north and south pole, as shown in the figure. A magnetic field is established between the poles by current flow in the field excitation winding. The rotor or armature rotates in this field. The windings on the armature cut the lines of magnetic flux, and a voltage is induced in the armature windings. Current is taken from the armature windings by brushes mounted on the commutator, and delivered to the load.

In this, as in all dc generators, an armature magnetic field is created by armature current. This is called the quadrature field, or cross field. It is perpendicular to the excitation field. This is the cause of armature reaction within the generator, and is an unwelcome feature of the normal generator.

In chapter 2, we saw an ordinary dc generator transformed into an amplidyne generator by making a few small, but consequential, changes in its makeup. Let us now take a closer look at this transformtion.



53.40

Figure 3-4.—Ordinary dc generator.

The first step in building an amplidyne generator is to short out the brushes (fig. 3-5). This establishes a path of very low resistance for the induced voltage in the armature winding under the brushes; consequently, we will have a large current in the winding. Now we can reduce the excitation and obtain the same armature current as in an ordinary generator.

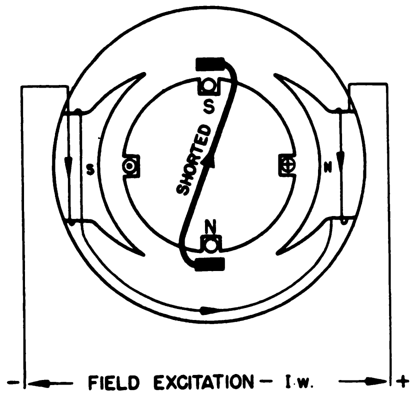
If we reduce the field excitation by a factor of 100, we reduce the field flux, which in turn reduces the induced voltage in the armature. The reduced armature voltage is now forcing current through a short-circuited armature winding. The shorted armature produces the same armature current as the loaded armature in an ordinary generator, but with only 1/100 as much field excitation.

The current flow in the armature is used to establish the quadrature or cross magnetic field. This is the same as in any ordinary generator. Figure 3-6, view A, shows the excitation field flux, and figure 3-6, view B, shows the flux caused by armature current. This view represents the mechanical (no load) situation.

ANSWERS TO QUESTIONS Q1 AND Q2.

A1. Stowing and maintenance only.

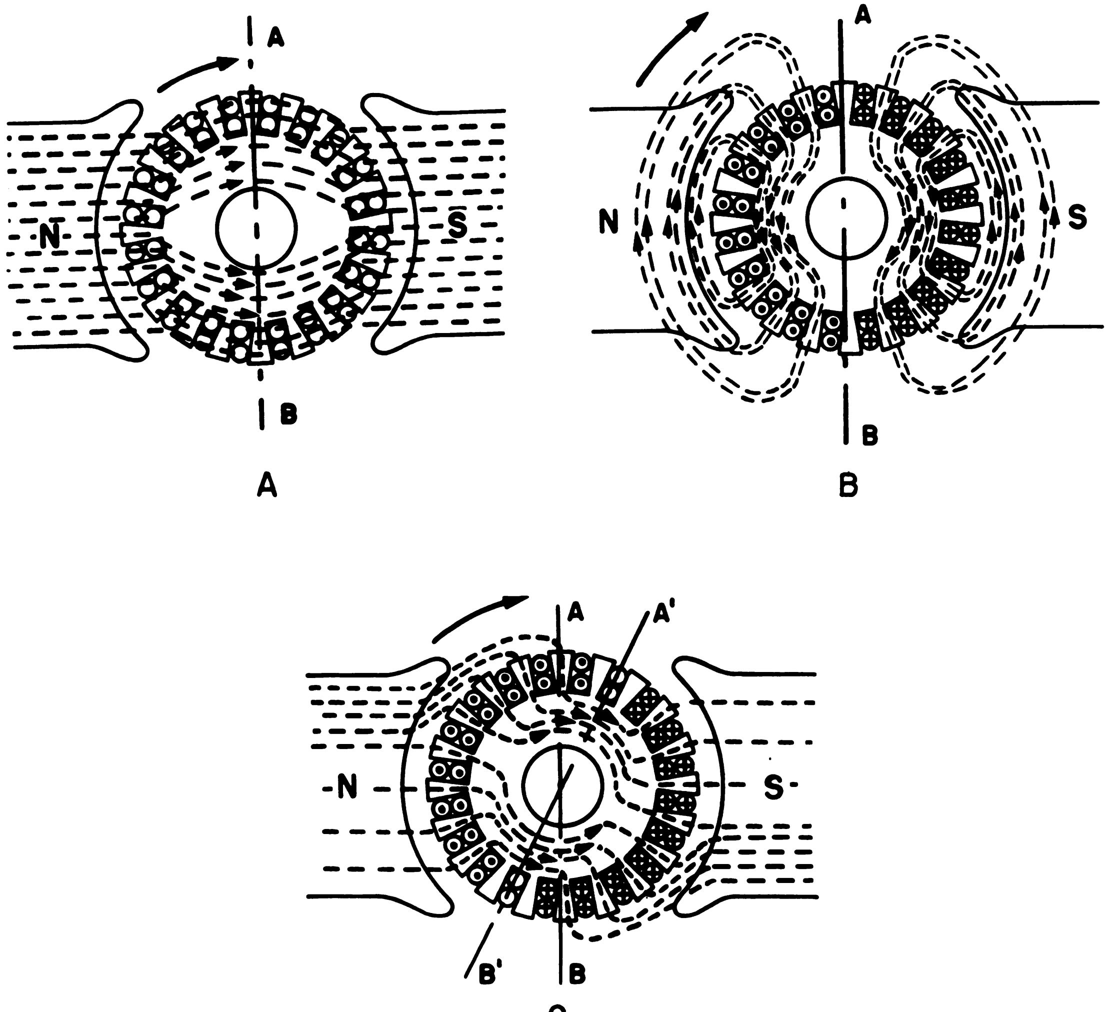
A2. The degree of displacement (for train) or tilt (for elevation) of the OMC.



53.41

Figure 3-5.—Quadrature brushes shorted.

When current flows in both the field and armature circuits, the two resulting magnetotive forces distort each other. They twist in the direction of rotation of the armature. This action causes the mechanical (no load) neutral plane A-B (fig. 3-6, view C) to advance to the electrical (load) neutral plane A'-B'. The amount that the neutral plane shifts is proportional to the load on the generator because the amount of cross-magnetizing flux is directly proportional to the amount of current flowing in the armature. The axis A'-B' is the line in which the shorted brushes lie. If the brushes remain in the old neutral plane, they will be short-circuiting coils which have



A. Field flux
B. Armature flux
C. Resultant flux

53.42

Figure 3-6.—Flux distribution in a dc generator.

voltage induced in them. Consequently, there will be arcing between the brushes and commutator.

To prevent arcing, the brushes must be shifted to the new neutral plane. Shifting the brushes to the advanced position (the new neutral plane) does not completely solve the problems of armature reaction. The effect of armature reaction varies with the load current. Each time the load current varies, the neutral plane shifts. This means the brush position must be changed each time the load current varies.

In small generators, the effects of armature reaction are reduced by actually mechanically shifting the position of the brushes. The practice of shifting the brush position for each current variation is not practiced except in small generators. In larger generators, other means are taken to eliminate armature reaction. COMPENSATING WINDINGS are used for this purpose. In the amplidyne generator, the shorted brushes are called the quadrature brushes.

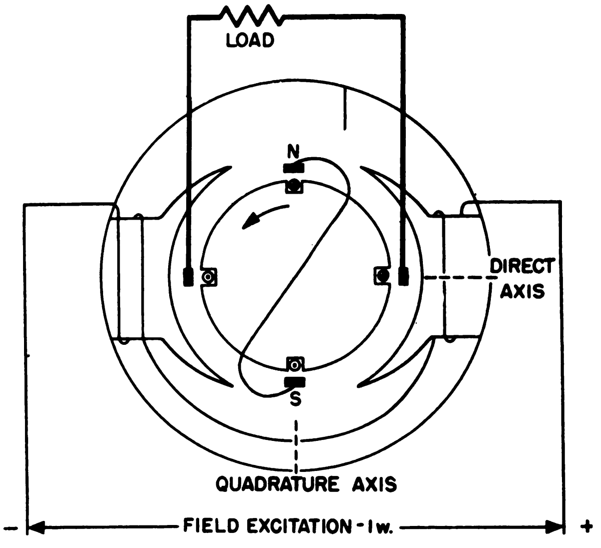
Q3. What is the first step in building an amplidyne generator?

LOAD BRUSHES

The quadrature field is the source of our output power. The windings of the armature cut the lines of flux in the quadrature field, and a voltage is induced. Be sure you understand that only the armature winding that is passing under the shorted brushes is short circuited. The other windings have normal resistance. We now add another set of brushes called the load or direct axis brushes (fig. 3-7). The axis of these brushes is perpendicular to that of the shorted brushes. The load brushes bear against the commutator, and take off the current induced in the armature windings by the strong quadrature field.

COMPENSATING WINDING

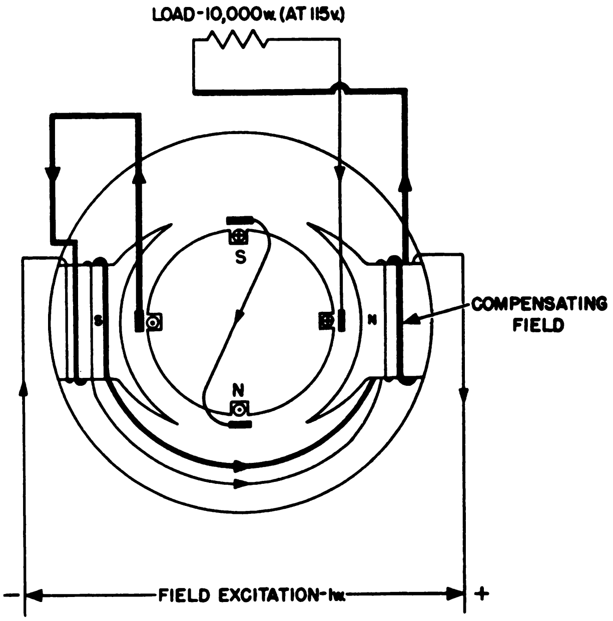
If the amplidyne generator is to work under a load, we need another winding. As soon as we have load current in the armature, we automatically establish another magnetic field due to armature reaction. The field is 90° away from the load brushes, as in an ordinary generator. But in the amplidyne generator, this puts the field caused by armature reaction in the same plane as our relatively weak excitation field. Because this field opposes the excitation field, it causes the power output to drop off rapidly.



53.43

Figure 3-7.—Connecting a load.

What we need is another winding to set up a field that will oppose the field created by the load current. We call this the compensating winding and connect it in series with the load, as illustrated in figure 3-8. Any current delivered to the load will pass through the compensating winding and



53.44

Figure 3-8.—Compensating windings.

create a magnetic field proportional to the load current. The windings are wound so that the field they set up will oppose the armature load current field. The two fields will be equal and opposite, and will therefore cancel one another. With the cancellation of load flux, the power output is normal.

CONTROL WINDING

Assume we have a power amplification of 10,000 to 1. Now we must be able to control it. If we are to use this amplidyne generator to drive a gun mount, we must be able to control both the direction and the amount of output power.

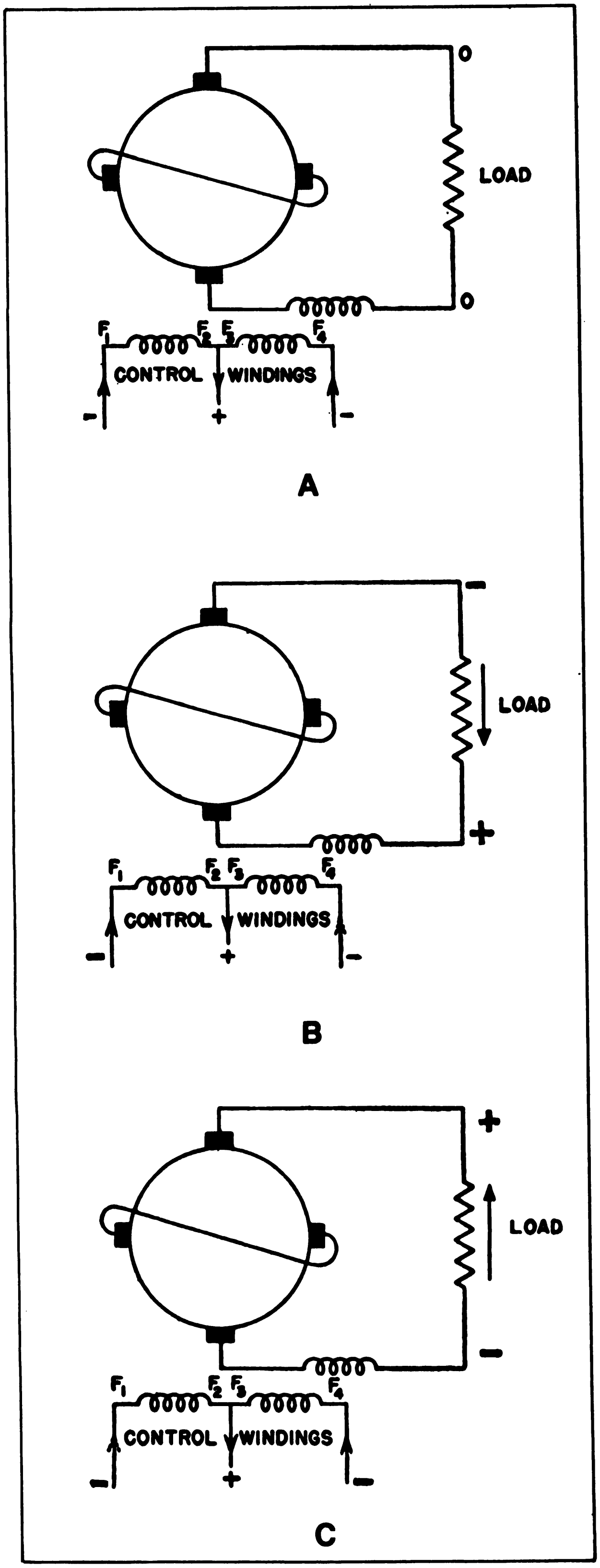
Until now, we have assumed that the signal going into the generator—the excitation voltage—is applied to a single control winding. Now let us split the control winding into two separate windings, and let them receive dc inputs of opposite polarity, as in figure 3-9. The resulting control fields oppose each other. If the inputs to the two control windings are equal and opposite, the fields they create will cancel. With no control field flux to create a quadrature flux, there is no output. This condition is shown in figure 3-9, view A.

Figure 3-9, view B, shows the inputs unbalanced, with the current in winding F1-F2 the stronger. This is shown in figure 3-9 by the large (bold) negative and positive signs on the F1-F2 winding. Now the control fields no longer cancel one another, for the field from winding F1-F2 is stronger. We will have an output, with a strength determined by the difference in the control windings' signal strength. Notice the direction of the output current.

Figure 3-9, view C, is the exact opposite of figure 3-9, view B; the F3-F4 control field is now stronger (bold negative and positive signs on the F3-F4 winding). Notice that the output is reversed. You can see, then, that the amount of output is determined by the resultant between the input signals applied to the control windings. The polarity, or direction of the output, is determined by which control winding receives the larger input signal.

HOW THE CONTROL IS USED

Here is an example of how the amplidyne control is used. The control windings are connected to the output of an amplifier, whose input signals come from train synchro control transformers on a gun mount. The F1-F2 control winding receives signals for left train. The F3-F4



53.45

Figure 3-9.—Two control fields.

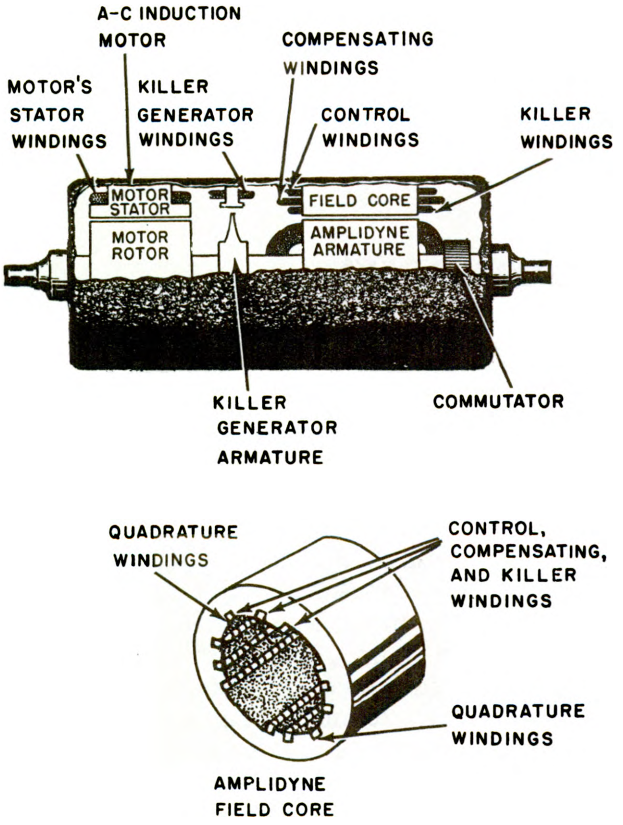
control winding receives signals for right train. The amplidyne output is connected to the train drive motor.

As long as the two signals are balanced, there is no output from the amplidyne. That means that there is no input to the drive motor, and the mount is stationary.

But when the F1-F2 input becomes stronger than the F3-F4 input, the amplidyne amplifies the difference between the two inputs. The output of the amplidyne has the F1-F2 polarity, and the drive motor rotates for left train.

Just the opposite happens when F3-F4 becomes stronger than the F1-F2 input. Again, the amplidyne amplifies the difference between the two inputs. But now the amplidyne output is reversed and the drive motor rotates for right train.

Now let us say that the difference between the F1-F2 and F3-F4 inputs becomes greater. This increases the control field strength, and thereby increases the amplidyne output. The increased output applies more torque to the drive motor. The gun mount moves faster because of the greater difference between the control windings' inputs.



53.46

Figure 3-10.—Complete schematic of the amplidyne.

ADDITIONAL FIELDS

What we have just discussed is a basic amplidyne generator. We will now take up some improvements that will give us more accurate power control, more sensitivity, and greater adaptability.

Killer Generator

The killer generator is a small ac magneto-generator. It has a permanent magnet armature mounted on the amplidyne armature shaft, and small field coils mounted on the amplidyne frame (fig. 3-10).

As the amplidyne shaft rotates, the permanent magnet induces an ac voltage in the small field coils. This ac voltage is connected to a demagnetizing winding, which consists of a few turns near the control and compensating windings. The demagnetizing winding carries alternating current, and its rapidly reversing field removes any residual magnetism left by the control or compensating fields when their current goes to zero.

Quadrature Field Winding

The quadrature field winding is wound on the amplidyne frame at right angles to the control winding. This means that the quadrature winding is in the same plane as the quadrature field established by armature current. If the quadrature field's strength is steady, the quadrature flux threads through the quadrature winding without inducing a voltage in it. There will be no induced voltage in the quadrature winding unless the

ANSWER TO QUESTION Q3.

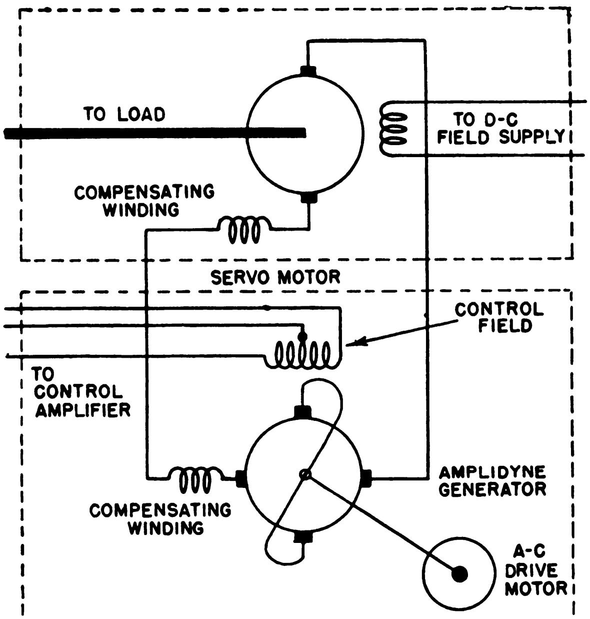
A3. Short out the brushes.

quadrature magnetic field changes in strength. The quadrature field is created by the induced voltage in the armature; hence, the induced voltage in the quadrature winding is a direct measurement of the rate of signal change in the control winding. This induced voltage is fed back to the amplifier to reduce overtravel and hunting by the gun mount.

COMPLETE PICTURE

Now we have a complete amplidyne generator as used in the Mk 35 power drive. Figure 3-11 shows a schematic diagram of the circuits in the generator. The action of the generator can be summarized as follows:

1. A very low-power input to the control field creates a large armature current due to the shorted brushes, thus producing a relatively strong quadrature or cross field. The armature windings cut the quadrature field, and a large voltage is induced. This voltage is delivered to the load through load brushes.
2. The magnetic field set up in the armature by load current is canceled out by the compensating winding field.
3. Residual magnetism is removed by an ac magnetogenerator.
4. The control winding is split into two windings, wound in opposite directions, to give more sensitive control.



53.47

Figure 3-11.—Basic amplidyne drive.

Q4. When the F1-F2 control winding receives a larger input signal, in what direction will the gun mount train?

Q5. What control winding effects the movement of gun mount train to the right?

GENERAL CHARACTERISTICS

Amplidyne generators are driven at relatively high speeds (1500 to 4000 rpms—depending on the type of generator used and its purpose). A common housing, for example, encloses both the motor and generator of the amplidyne in the Mk 35 power drive. The ac motor is a two-pole 440 vac, 3-phase induction unit designed for starting by signals received from the control panel. Order signals from these controls are fed to separate train and elevation amplifiers which increase signal power. The amplified signals are supplied to the amplidyne motor generators which, in turn, supply dc power to the elevation and train drive motors. Amplidyne generators respond quickly to changes in control field current.

The delay between a change in the magnitude of the control field current and the resulting change in load current is about 0.1 second.

A limitation on the size of the amplidyne results from commutation of the self-induced voltage in the coils, and the consequent sparking at the commutator.

An amplidyne generator, in converting mechanical energy into electrical energy, can be compared to a pump which pumps electrons through wires. It forces electrons out through one wire and pulls them back in through another. This action is similar to that of the A-end pump in a hydraulic drive. The dc drive motor on the gun mount converts the electrical energy back into mechanical energy. This action is similar to that of the B-end hydraulic motor.

The advantages of the amplidyne drive are as follows:

1. It responds rapidly to small signals.
2. It delivers power smoothly.

3. It is a very flexible installation because it is all electrical.

4. Most of its control equipment can be located below decks.

Q6. An amplidyne generator converts mechanical energy into what?

TRAIN AND ELEVATION DRIVE MOTORS

The train and elevation drive motors on 3"/50 gun mounts are identical. Both are 8.5 hp, dc motors with a separately excited shunt-field winding. The inputs to the motor are the field excitation current from the motor field control unit in the amplifier, and the control current from the amplidyne generator. The control current is applied to the armature of the motor.

The characteristics of a shunt motor are covered in the NEETS, module 5. Here, only the operational features, plus the reasons for using this type of motor, will be discussed.

The operational features of a shunt motor are that the output torque varies linearly with input current throughout the designed range of input currents. You can see, then, that if the load is constant and the current is increased, the motor will speed up. The load on the motor is the armament, which has a constant weight. As the control current from the amplidyne increases or decreases, the motor will increase or decrease its speed in proportion. The field excitation remains constant at 1.4 amps.

Another advantage of the shunt motor is a fairly constant speed under a variable load. When the armament is tracking a target with a constant angular rate, the armament will follow smoothly. If the control current from the amplidyne is constant, the armament will move at a constant angular rate until the signal is changed. This is true regardless of the load put on the motor by the angular rate of the armament (provided the load is within the design limits of the motor).

Since the amplidyne is the source of armature excitation current, we can change the direction of motor rotation by changing the excitation polarity. We can also change the motor speed by increasing or decreasing the amplidyne's current output.

The series compensating winding has the same function in a shunt motor as in the amplidyne generator. Armature reaction is caused by current in the motor armature, but the flux revolves in the opposite direction from that of the generator. The armature reaction is overcome by the compensating field.

The amplidyne generator and the drive motor are not continuous duty devices. They are rated for 1-hour intermittent operation. With intermittent operation, the generator and motor temperatures will not rise beyond acceptable limits. The equipment can produce a large power output for a short period of time.

Q7. What is the rated operating time of an amplidyne generator and drive motor?

POWER CONTROL CIRCUITS

Before going into the actual circuitry, we should take a look at the elements employed to get familiar with their functions. Most of the elements are simple devices already familiar to you.

A CIRCUIT BREAKER is a device that opens a circuit while carrying current. It protects the circuit from abnormal conditions, such as low power supply or overload.

A RELAY is an electrically-operated device for opening and closing a circuit. A small power source can be used to operate a relay, which in turn connects a large power source to the load. The relay can be operated from a remote station. Relays can control a timed sequence of operations.

An OVERLOAD RELAY is similar to a circuit breaker. It protects the equipment

ANSWERS TO QUESTIONS Q4 AND Q5.

A4. To the left.

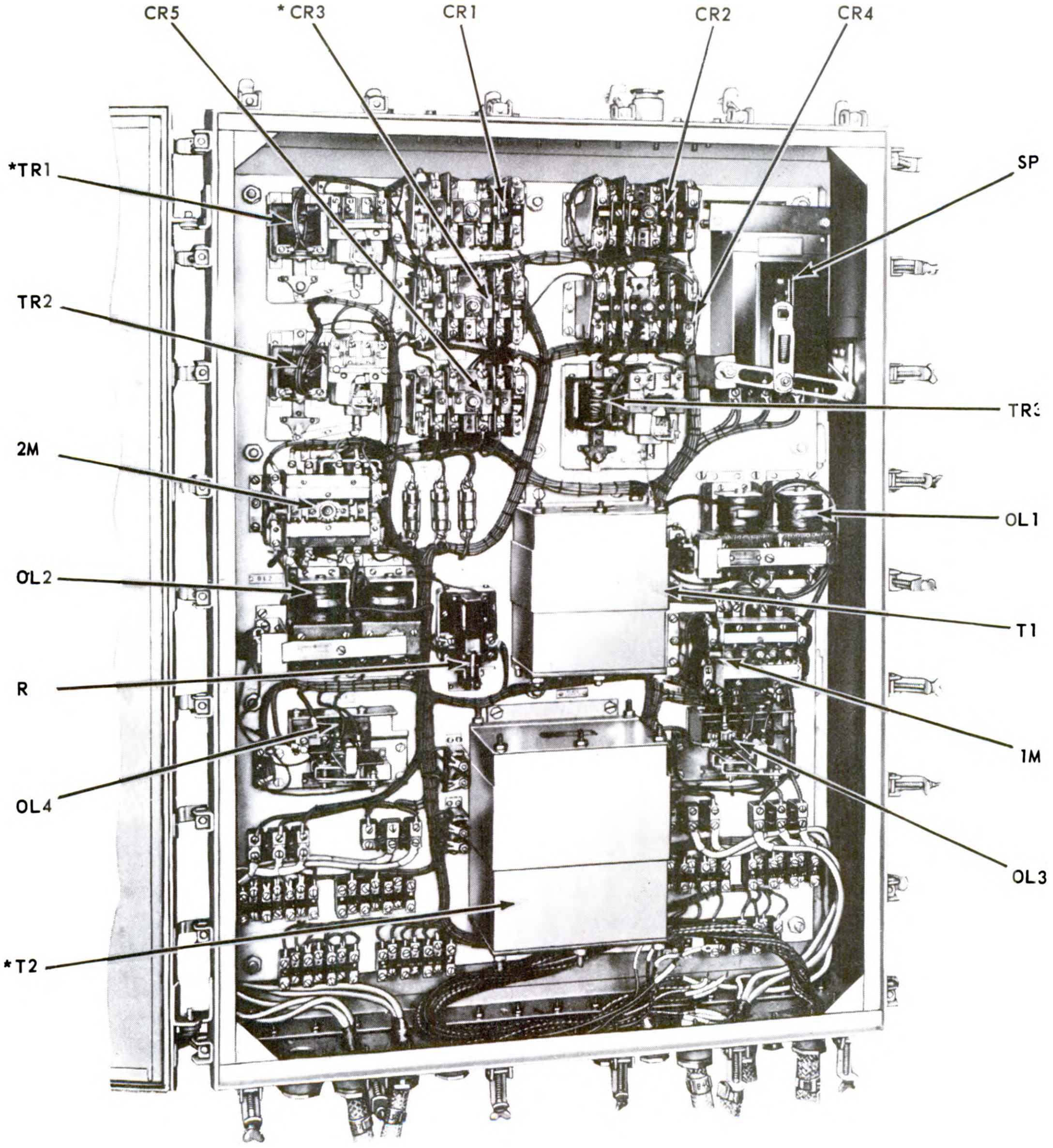
A5. F3-F4.

from excessive current by opening the circuit.

INTERLOCK SWITCHES are safety switches connected in series with the starting and holding circuit of the drive, so that the drive cannot be started unless certain conditions exist. These switches are there to protect both personnel and equipment.

We will use the power control circuits in the Mk 35 power drive as an example. Although the circuits of other amplidyne drives may differ in detail, they all operate on the same basic principles.

The electrical supply necessary to operate the power drive is 440-volt, 3-phase, alternating current supplied to the Mk 65 control panel (fig. 3-12). If the armament is to be operated in



LEGEND

*TR1	TIMING RELAY	CR1	CONTROL RELAY	SP	AIR CIRCUIT BREAKER
TR2	ELEVATION TIMING RELAY	CR2	CONTROL RELAY	TR3	TRAIN TIMING RELAY
2M	ELEVATION LINE CONTACTOR	*CR3	CONTROL RELAY	OL1	TRAIN OVERLOAD RELAY
OL2	ELEVATION OVERLOAD RELAY	CR4	CONTROL RELAY	1M	TRAIN LINE CONTACTOR
R	RELAY ELEVATION	CR5	CONTROL RELAY	OL3	TRAIN OVERLOAD RELAY
OL4	ELEVATION OVERLOAD RELAY			T1	CONTROL TRANSFORMER
				*T2	PLATE SUPPLY TRANSFORMER

*THESE ITEMS MAY BE PRESENT ON UNITS ORDALTED IN THE FIELD BUT HAVE BEEN DISCONNECTED.

53.48

Figure 3-12.—Control panel Mk 65 Mod 4, interior view.

automatic, a power supply for synchro operation is also required as an input to the control panel. In the control panel, usually mounted below decks, is a circuit breaker which controls the 440-volt supply for both train and elevation. The circuit breaker can be operated by a handle to serve as a main disconnect switch. It also has a thermal overload device that will open the circuit automatically if the line current becomes excessive.

When the circuit breaker is closed, it energizes transformer T1. Transformer T1 energizes all the filament transformers in the amplifier except those of the parallax amplifier. The parallax amplifier receives its supply from the parallax synchro voltage.

T1 also energizes a blower motor in the amplifier housing and provides a source of 115-volts alternating current for the power control circuit.

Before the amplidyne can be started, the interlock switches for both train and elevation must be closed. These switches are in series with the power supplies. They are safety devices, and should never be bypassed (shorted out) or tampered with. You will find them associated with the armament securing devices, brakes, and manual drive mechanisms. Interlock switches are often used in electrical and electronic equipment, so that opening the cover or door will operate the switches and open the high voltage circuits.

The overload relays must be in the operating position with their contacts closed. There are four thermally-operated overload relays in this power drive. They protect the train and elevation drive motors and the amplidyne generators. If one of the relays should be tripped, it would deenergize the field supply of both the generators and the motors, and also set the brakes.

Q8. What is the purpose of an overload relay?

Q9. What transformer energizes the blower motor in the amplifier housing?

MOTOR START SWITCHES

For gun mount operation, the control selector switch SM1 on the gun control panel (GCP) must be in one of the LOCAL positions before starting the gun mount's amplidyne motors. This is to keep the mount drive in local control until its operation has been tested. Figure 3-13 shows the circuit ready for the first sequence of operation when in local control. All that remains to be done is to push a start button on the gun control panel. For clarification, and to enable you to follow the circuitry explained in the following paragraphs, the contacts of the relays in this figure have been labeled. The START pushbutton completes circuits to the train contactor 1M and auxiliary relay R. You can trace this circuit in figure 3-13 from the ACC side of T1 through the CONTROL selector switch, the START and STOP buttons, the interlocks and overload relays, and the coils of 1M and R to the ACC side of T1. Contactor 1M immediately starts the train amplidyne and closes a circuit in the parallax amplifier plate supply through deck 5, contacts A and B. Another set of contacts, deck 4, contacts A and B of 1M, in series with contacts 1 and 2 of R, connects the ACC line to a point between the START and STOP pushbuttons. This shorts out the START button so it can be released without opening the circuit. The same contacts of 1M and R also actuate relay TR2.

Contacts 1 and 2 of TR2 are in series with the coil of relay 2M. Therefore, relay 2M cannot operate until relay TR2 has operated. TR2 has a time delay device of the definite-time type. It is operated by a solenoid that compresses a metal bellows. The air trapped in the bellows escapes gradually through a needle valve, which can be adjusted to determine the length of the time delay.

Time delay TR2 is set at 8 seconds to give the train amplidyne time to reach operating speed. From your study of motors, you will remember that there is a large starting current in all motors. The overload is present until a counter-electromotive force is built up in the armature of the motor. The delay provided by TR2 ensures

ANSWERS TO QUESTIONS Q6 AND Q7.

A6. Electrical energy.

A7. 1-hour of intermittent operation.

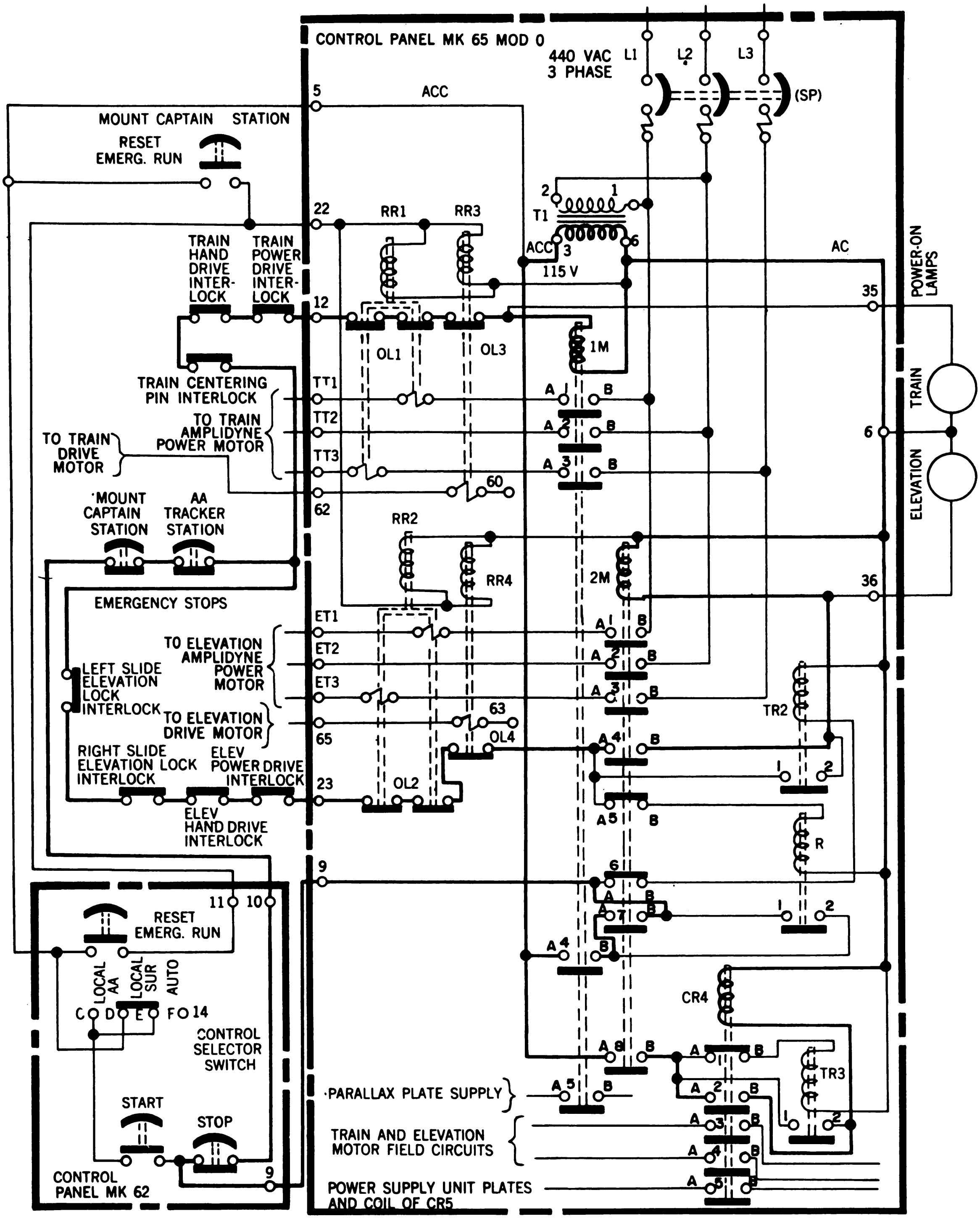


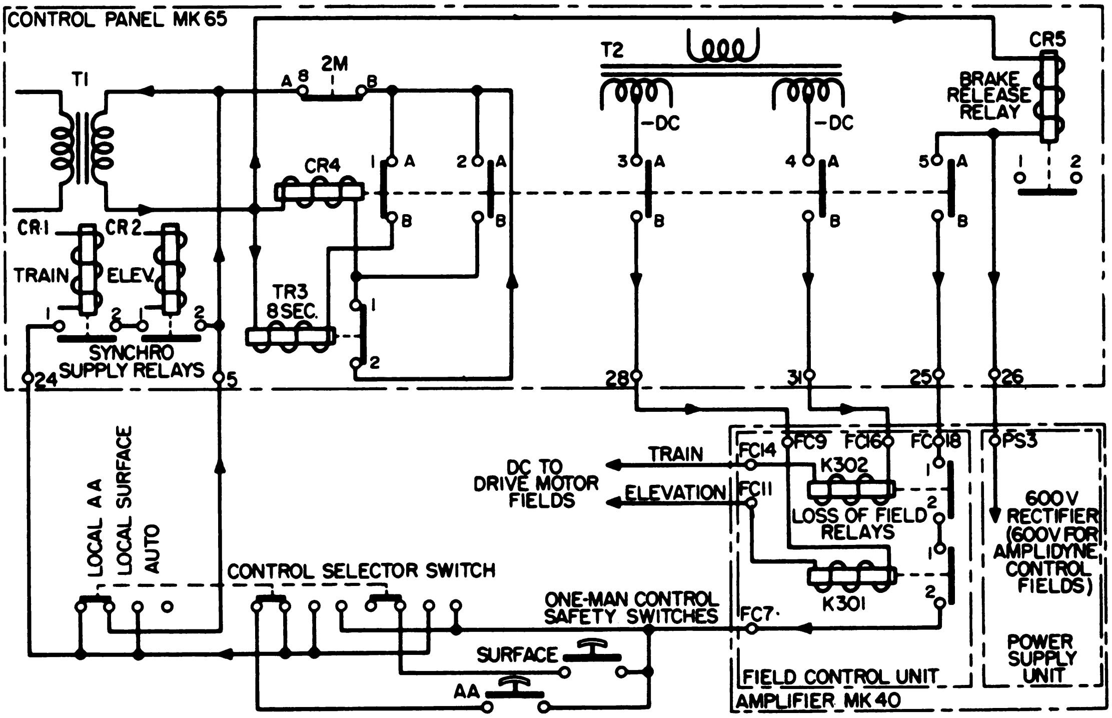
Figure 3-13.—Power and control circuits for train and elevation power drives.

that the overloads caused by starting the train and elevation amplidyne generator motors will not be present simultaneously.

When TR2 picks up at the end of 8 seconds, elevation line contactor 2M is actuated. This allows the 440 vac, 3-phase power, to start the elevation amplidyne power motor through the A and B contacts of decks 1, 2, and 3 of 2M. At the same time, the A and B contacts of decks 5 and 6 of 2M will open and deenergize the coils of R and TR2. However, contacts 1 and 2 of TR2 are bypassed by deck 4 contacts A and B of 2M in order to keep 2M energized. At the same time, deck 7 contacts A and B of 2M bypasses contacts 1 and 2 of R to keep the circuit energized. Thus, the circuits set up by R and TR2 are maintained, although the relays are permitted to drop out.

Contacts A and B of deck 8 of 2M energize the coil of timing relay TR3 (fig. 3-14). TR3 operates after 8 seconds, which gives the elevation amplidyne time to come up to speed, and the cathodes of the thyratron tubes in the motor field control unit time to warm up. Operation of TR3 energizes the coil of control relay CR4, whose contacts maintain the circuit through its own coil, and open the circuit through the coil of TR3. CR4 controls the plate supply for the control fields of the train and elevation amplidynes, and completes the field circuits for the train and elevation drive motors through the A and B contacts of decks 3 and 4. CR4, when operated, also energizes the coil of brake release relay CR5 through the A and B contacts of deck 5. To energize CR5, it is necessary that control relay CR4 and loss-of-field relays K301 and K302 also be energized through the A and B contacts of decks 3, 4, and 5 of CR4.

In addition, the safety switches on the appropriate OMC must be closed when in local control. Both synchro supply relays CR1 and CR2 must be energized when in automatic control. The coils of CR1 and CR2 are energized by the elevation and train synchro reference supply. The loss-of-field relays are energized by the current



53.51

Figure 3-14.—Relay circuits CR4, TR3, and CR5.

ANSWERS TO QUESTIONS Q8 AND Q9.

A8. *It protects the equipment from excessive current by opening the circuit.*

A9. *Transformer T1.*

that supplies the field of the train and elevation drive motors.

Thus, before the train and elevation brakes can release, two things must happen. First, the fields of the train and elevation drive motors must be energized. Second, the train and elevation synchro circuits must be energized (if in automatic control), or the proper safety switch must be closed (if in local control).

When the circuit to CR5 is completed, the 600-volt section of the power supply unit will also be energized. This section supplies 600 volts direct current to the train and elevation amplidyne control field circuits.

Q10. What is the reason the time delay TR2 is set at 8 seconds?

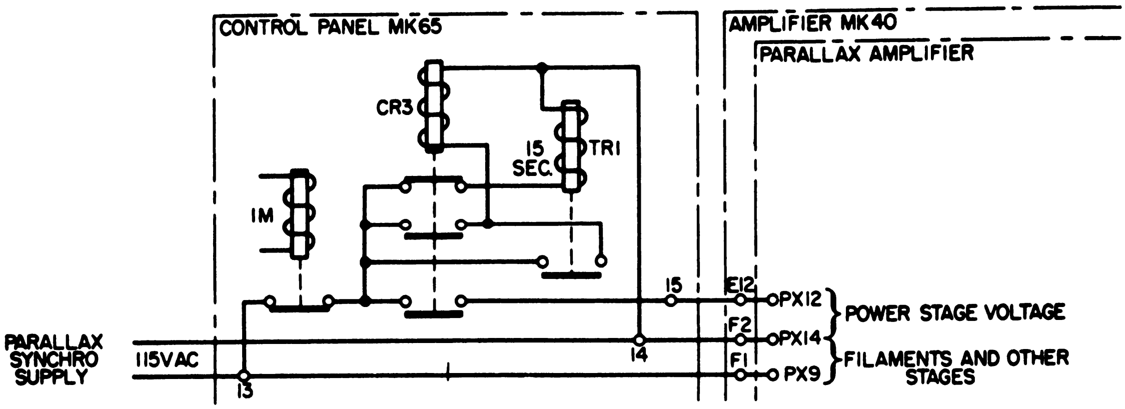
PARALLAX AMPLIFIER POWER SUPPLY CIRCUIT

Recall from your study of parallax in *GMG 3 & 2* that the purpose of a parallax correction system is to introduce parallax corrections in train to compensate for the actual base length between the gun director and gun mount. This is accomplished by a parallax motor, parallax change gears, and a parallax amplifier. Supply for the power stage of the parallax amplifier goes through the contacts of relays 1M and CR3 (fig. 3-15).

When line contactor 1M operates to start the train amplidyne, its contacts also energize timing relay TR1 in the parallax control circuit. After 17 seconds, TR1 will pick up and energize CR3 to complete the power circuit. This delay provides enough time to heat the cathodes of the power tubes in the parallax amplifier. Other contacts of CR3 bypass the contacts of TR1, and break the TR1 holding circuit. If the supply voltage fails, or 1M releases to shut down the equipment, the power circuit cannot be restored without again going through the timing cycle of relay TR1.

OVERLOAD PROTECTION CIRCUITS

Overload protection for the control circuits (local AA and local SURFACE) is provided by the circuit breaker and overload relays. When one of the overload relays drops out, it may be reset electrically by depressing the RESET/EMERGENCY RUN button. A RESET/EMERGENCY RUN is located on the LOCAL SURFACE operator gun control panel and mount captain's panel for gun mount operation. If, in an emergency, you have to resume power operation immediately after an overload, you will have to simultaneously depress the RESET/EMERGENCY RUN button while depressing the START button. Then, release the START button and continue holding down the RESET/EMERGENCY RUN button for 16 seconds. This is necessary because the overload relays contain a thermal device that must cool off before the overload contacts will stay closed. Operating the power drive with this button depressed, bypasses the protective function of the overload relays. The reset relays are energized by holding the overload contacts in the closed position. You should, therefore, use this method of operation only in extreme emergencies. When an overload has been actuated, the cause of the overload should be investigated and corrected before trying to resume power operation.



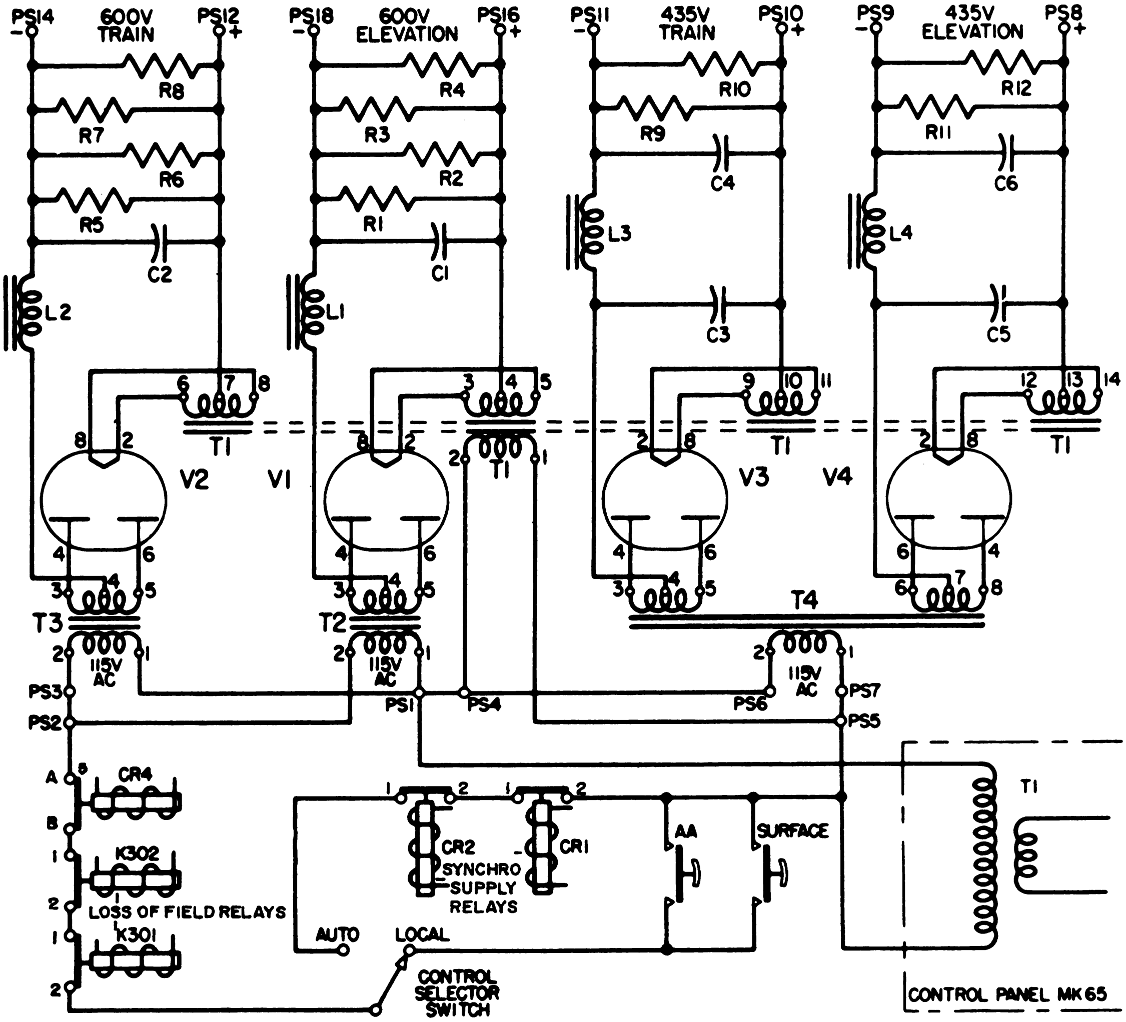
53.52

Figure 3-15.—Relay circuit CR3.

Q11. How long must you hold the RESET EMERGENCY RUN pushbutton to re-energize the train and elevation circuits?

POWER SUPPLY UNIT

The dc power supply unit consists of rectifiers providing dc power at 435- and 600-volts (fig. 3-16) to the train and elevation amplifiers. Plate supplies for the 435-volt rectifiers are taken from transformer T4 fed by T1 in the Mk 65 control panel, which also furnishes filament power. For local operation, the plate voltage for the 600-volt rectifier are taken from T1, through T2 and T3, through contacts of relays CR4, K302, K301, one of the safety switches, and the control selector switch. For automatic operation, the plate voltage circuit for the 600-volt rectifier must be completed



53.54

Figure 3-16.—Power supply unit.

ANSWER TO QUESTION Q10.

A10. To allow the train amplidyne to reach operating speed.

through the contacts of synchro supply relays CR1 and CR2. If the elevation or train synchro supply fails, CR1 or CR2 will open and deenergize the supply for the 600-volt rectifier. Relays K301 and K302 will also deenergize this supply if either drive motor field loses excitation.

Since the rectified voltages supply plate voltage for the train and elevation amplifiers, which in turn supply control field current for the amplidynes, the circuit just described must be completed before the amplidynes can be excited. This same circuit also energizes the brake release relay.

SAFETY

Much has been written on the subject of safety. Familiarity with the operation of a mechanism often leads to carelessness and overconfidence. Details on safety pertaining to amplidyne power drives are found in individual OPs. All personnel involved in maintenance of the amplidyne power drives are responsible for observing the safety precautions and instructions published by the Naval Sea Systems Command.

The following safety precautions are especially important when performing maintenance on these power drives:

1. Use the safety devices provided to ensure safe operation of the equipment.
2. Before opening the control panel cover, turn off mount power and tag all switches to warn personnel that work is being done on the equipment.

SUMMARY

In this chapter we briefly discussed how an amplidyne power drive controls the movement of certain gun mount systems. We covered the basic configuration of an amplidyne generator and its relation to the power drive, its functional use in the Mk 35 system, and its various operating characteristics. Emphasis was placed on the amplidyne generator. Train and elevation drive motors were also discussed; as well as the elements constituting the various power control circuits and step-by-step safe operation of these drive motors.

A review of the material covered in NEETS, module 5, will refresh your training in electric circuitry of generators and motors. NAVSEA OP 1753 will provide system specifics on the operation and maintenance of amplidyne power drives.

REFERENCE LIST

The following reference materials were used to develop the information presented in this chapter.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

3-Inch 50-Caliber Twin Gun Mount, Mark 33 Mods 0 and 13 Description, Operation, and Maintenance, OP 1753 Volume 1, Second Revision, Naval Sea Systems Command, Washington, D.C., July 1981.

Navy Electricity and Electronics Training Series (NEETS), Module 5, *Introduction to Generators and Motors*, NAVEDTRA 172-05-00-79, Naval Education and Training Program Development Center, Pensacola, Fla., 1979.

ANSWER TO QUESTION Q11.

A11. 16 seconds.

CHAPTER 4

AMPLIDYNE CONTROL EQUIPMENT

In the preceding chapter we discussed the basic principles of amplidyne power drives and the function of their major components. In this chapter we will discuss the devices and circuits which control power drives.

To understand this chapter, you must know something about electronics. We will assume that you have read the basic modules on vacuum tubes and amplifiers in the Navy Electricity and Electronics Training Series (NEETS).

By way of review, we will discuss a few of the general characteristics of some devices involving the flow of electrons that will have wide usage throughout this chapter.

Electron flow is caused by a difference in potential; electrons will flow to equalize two different energy levels. Electrons flow from negative to positive, or from negative to less negative, or from positive to more positive.

A capacitor, when charged, stores electrical energy. Under some conditions a capacitor tends to oppose any change of voltage in the circuit. Electrons cannot flow through a capacitor but they can flow into it or out of it, and thus produce a charge on its plates. Capacitors block the flow of direct current, but pass alternating current. They take time to charge and discharge; the length of time depends on both the size of the capacitor and the amount of resistance in the circuit.

Capacitors are used as filters to oppose changes in voltage and to smooth out the voltage ripple in power supplies. They are also used as couplers to pass alternating current or pulses while blocking direct current.

Inductors oppose changes in the current through a circuit. The choke coils illustrated in this chapter are inductors. An inductor offers a relatively high resistance to alternating current and a relatively low resistance to direct current.

Q1. Does a capacitor block the flow of ac or dc?

ELECTRON TUBES

An electron tube controls the flow of electrons, much as a valve in a hydraulic power drive controls the flow of fluid.

ELEMENTS OF A TUBE

The cathode emits electrons into the area around it, creating a space charge. When the cathode is heated, its electrons speed up until some of them escape from the cathode material. This process is called thermionic emission. When a heated cathode is to be used as an emitter, the air must be removed from the tube envelope, or enclosure, to keep the cathode from burning up and to permit a steady flow of electrons through the tube.

The plate (anode) of the tube attracts electrons from the cathode's space charge. Vacuum tube circuits are so designed that the plate has a positive potential with respect to the cathode.

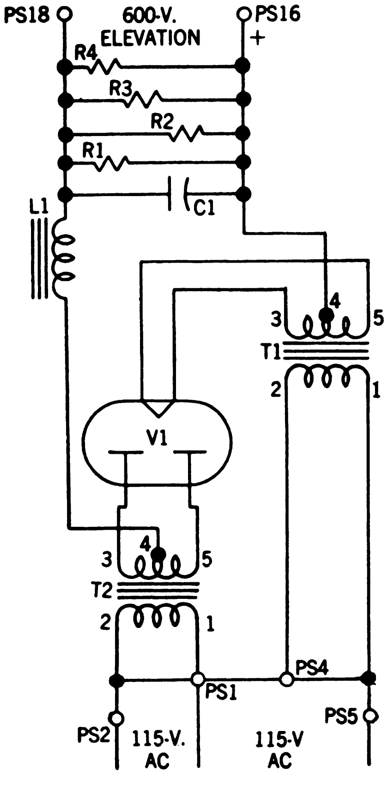
The grid is a third electrode, mounted between the cathode and the plate. The voltage applied to the grid controls the flow of electrons through the tube.

Diode Tubes

A diode has only two electrodes—cathode and plate. Since current can flow in only one direction—from cathode to plate—the diode serves as a rectifier. If you apply alternating current to a diode, current will flow only when the plate is positive; on the other half cycle, when the plate is negative, the tube is an open circuit. Thus a single diode can be used as a half-wave rectifier. For full-wave rectification, we need two diodes.

Figure 4-1 shows a twin diode tube, V1, which consists of two diodes in the same envelope. The circuit illustrated is a part of the power supply unit of the Mk 35 power drive; it furnishes the plate supply voltage for the elevation amplifier.

Transformers T1 and T2 are supplied with 115 volts alternating current. T1 supplies filament heater voltage to the tube, while T2 supplies plate voltage. The two plates are connected to opposite ends of T2. Thus, when the alternating current flows in one direction, one plate will be positive; when the current changes direction, the other plate becomes positive. Within the tube, current will flow from the cathode to whichever plate is positive. From the plates, current flows through the secondary of T2 to the center tap (number 4).



53.55

Figure 4-1.—Power supply unit.

Output current flows from the tube in only one direction, in spite of alternations of the ac supply. You may wonder what keeps the output current from rippling (rising and falling) as the two plates alternately pass current. The ripple is removed by the action of choke coil L1, and capacitor C1.

L1, the choke coil, is a filtering device which opposes any change in current. It passes direct current with little resistance, but shows a high resistance to the ripple current. A choke coil provides good current regulation.

When the tube begins to pass current, C1 starts to charge. When current through one plate of the tube starts to decline, C1 will discharge in opposition to the reduction of potential. Before it can discharge completely, the other plate conducts and the capacitor charges again. This action continues until the capacitor is at almost the full voltage of the positive pulses from the plates. The capacitor acts as a reservoir which will discharge into the load when the voltage decreases. These actions smooth out ripple in the dc output.

The load on the rectifier is not shown in figure 4-1. Actually, it is the plate circuits of the last stage of amplification in the elevation amplifier. Resistors R1, R2, R3, and R4 are in parallel with the load, and help to compensate for variations in load demand on the rectifier.

To complete the circuit, current flow exits the power supply at terminal PS18, proceeds to the amplifier circuits, and returns to the power supply through terminal PS16. From terminal PS16, current is returned to the cathode of V1 through the center tap (point 4) on the secondary of transformer T1.

Triode Tubes

The triode tube has three electrodes—plate, cathode, and grid. The grid is an open mesh of fine wire between the plate and the cathode. Electrons flow through it with little interference. The potential on the grid controls the electron flow through the tube. Grid potential is measured with respect to cathode potential and is called bias.

ANSWER TO QUESTION Q1.

A1. Dc.

A highly negative bias will cut off the current flow entirely. As the grid bias becomes less negative, current flow increases, and approaches a maximum when the grid potential is the same as that of the cathode. Because a small change in grid voltage causes a large change in plate current, the triode vacuum tube can be used as an amplifier. Triode amplifiers are used in power drive control circuits to operate relays and to amplify weak gun order signals.

Q2. What are names given to the two electrode elements of a basic diode tube?

Q3. What is the name given to the third electrode element of a basic triode tube?

GUN CONTROL CIRCUITS

As an example of gun control circuits, we have chosen those of the Mk 35 amplidyne power drive. You studied the function of this power drive in chapter 3. Since the synchro and amplifier circuits for train and elevation are practically identical, we will discuss only the train control circuits here.

From chapter 3 you learned that in automatic control, synchro control transformers in the receiver-regulator compare the actual train angle of the mount with the train order from the remote control station. If there is a difference between the two, the control transformers will generate an ac error signal, and transmit it to the amplifier. The phase of this error signal indicates the direction of the error, and its voltage amplitude indicates the amount of error.

In local control, the ac error signal is generated by an unbalanced bridge circuit in the one-man control (OMC) unit. We will discuss this in more detail later.

The reference voltage with which the error signal voltage is compared in the amplifier is 115 volts alternating current. In automatic control it is obtained from the synchro supply. In local control it is obtained from transformer T1 in the Mk 65 control panel.

Q4. In what gun control mode is the ac error signal generated by an unbalanced bridge circuit in the OMC unit?

THE TRAIN AMPLIFIER

The function of the train amplifier is to supply two control field currents to the amplidyne generator.

The train amplifier receives a low power error signal from the gun order transmission system, or from the OMC station, depending on whether the mount is in automatic or local control.

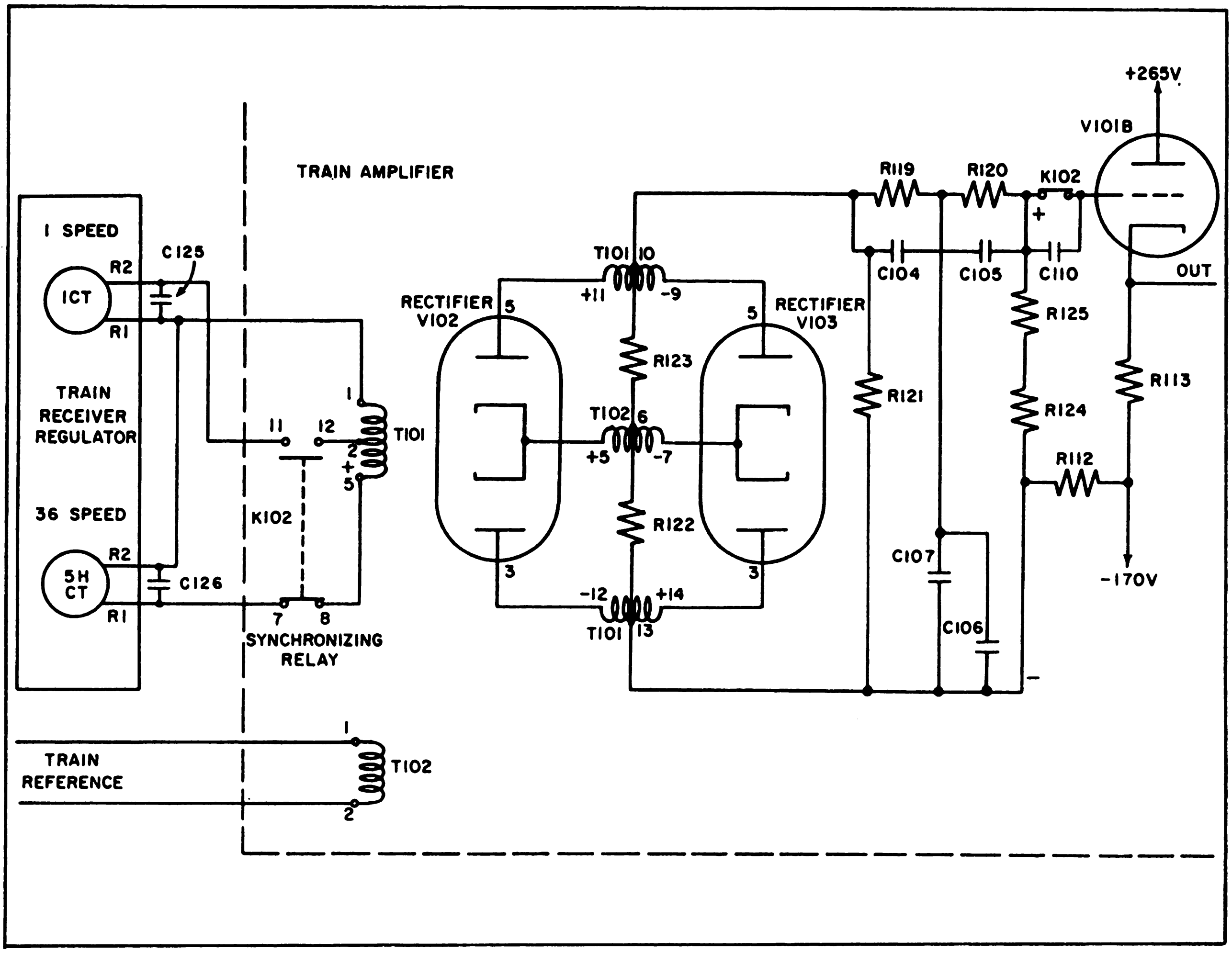
In the first of the three stages of the amplifier, the signal is rectified—that is, changed from alternating current to direct current. The amplifier then determines the direction of the ordered movement from the polarity of current flow. In the second stage the signal voltage is amplified. In the third stage the signal power is amplified. The output from the third stage is fed directly to the control winding of the amplidyne generator.

Function of the First Stage

The first stage of the train amplifier, illustrated in figure 4-2, is primarily a rectifier stage in which dc voltages are produced. At the left in figure 4-2 are the signal sources (1- and 36-speed control transformers and the train reference voltage) located in the train receiver-regulator. You can see how the 36-speed error signals reach the primary winding of transformer T101 through the normally closed contacts of synchronizing relay K102. The purpose of capacitor C126, across the primary of T101, is to remove sharp peaks from the error signal in 36 speed. (C125 removes the sharp peak in 1 speed.) The signal current flows from transformer T101 through tubes V102 and V103. The first stage amplifier is coupled to the second stage through tube V101B.

V102 and V103 are duodiodes, used to rectify the signal and compare it with the reference voltage. The ac signal voltage supplies plate voltage to both tubes through T101.

The end taps of the secondary windings of T101 are connected to the plates of rectifier tubes V102 and V103. The cathode potentials are determined by the ac reference voltage through T102. The cathodes of V102 and V103 are connected to the end taps of the secondary transformer T102, whose primary receives the 115-volt ac reference voltages that also energize the rotor of the 36-speed synchro transmitter in the fire control system.



53.56

Figure 4-2.—First stage of the train amplifier; simplified schematic.

The reference voltage determines which of the rectifier tubes will pass current during any given half cycle. Simultaneously, the error-signal voltage determines which half of the firing tube will pass the greater current.

Plus and minus signs at transformer T102 indicate the polarities for one-half cycle. Because the cathodes of V103 are connected to negative transformer tap (-7), they are negative with respect to the plates, and V103, therefore, draws current. Current will flow only from negative to positive, or from negative to less negative. The cathodes of V102 are connected to positive taps, and V102 is dead and cannot conduct because its cathodes

ANSWERS TO QUESTIONS Q2 THROUGH Q4.

A2. Cathode and plate.

A3. Grid.

A4. Local.

are positive. On the opposite half cycle the conditions are reversed; V102 draws current and V103 is dead. When the mount is in correspondence with the 36-speed signal, there is no error signal voltage and both plates of the firing tube V103 have the same potential. The two plates then draw equal currents, the upper plate through R123 and the lower plate through R122. Since current flow is in opposite directions in the two resistors, the voltage drop in one cancels the voltage drop in the other, and the net voltage difference across resistors R122 and R123 is zero. This voltage difference constitutes the output of the first stage, which is applied through filter resistors R119 and R120 across R125 and R124 in the grid circuit of cathode follower V101B. Thus, for zero error signal, the output of the first stage is zero.

RIGHT TRAIN SIGNAL.—An error signal calling for right train affects the polarity of the taps of T101, as indicated by the plus and minus signs (fig. 4-2) for the half cycle in which V103 is firing. Plus and minus signs at the taps of T102 show reference voltage polarities for the same half cycle. The right train signal changes the potential of the upper plate (5) of the firing tube V103 in the negative direction, and the tube therefore draws less current through resistor R123. The lower plate (3) voltage changes in the positive direction, and current in R122 is increased. The voltage drop in R122 is now greater than in R123, and the upper end of R123 becomes positive with respect to the lower end of R122. This potential difference will appear across R124 and R125 and have the same polarity. The result of a right train signal is to change the grid voltage of tube V101B in the positive direction.

For the second half cycle, all ac polarities in T101 and T102 are reversed, and V102 becomes the firing tube. For a right train signal, the upper plate (5) of V102, being connected to a minus tap of T102, draws a light current through R123. Its lower plate (3), connected to a positive tap, draws a heavy current through R122. Thus, the result of a right train signal is the same for both half cycles—a more positive input to the grid of tube V101B.

LEFT TRAIN SIGNAL.—For a left train error signal, polarities in T101 are reversed from those shown in figure 4-2, while those in T102 remain the same. Because the changes in plate voltage have the opposite strengths, the upper plate (5) of V103 draws heavy current through R123, while the lower plate (3) draws less current through R122. On the second half cycle, the upper (5) and lower (3) plates of V102 do the same. The voltage drop in R123 is then greater than that in R122, and the upper end of R123 becomes negative with respect to the lower end of R122. The result of a left train signal is to change the grid voltage of tube V101B in the negative direction.

The function of the first stage, then, is to change the signal from alternating current to direct current, and then to compare the amplitude of the signal voltage (an electrical indication of how far the gun is out of correspondence) with the reference voltage. The source of the reference voltage is the same as that used to generate the signal voltage.

The phase difference between the two controls the polarity of the signal output (an electrical indication of which direction the gun must move to align with the order signal) to V101B. V101B is used to couple the first amplifier stage to the second. A relatively positive signal on the grid of V101B will produce a positive output signal at the cathode, while a relatively negative signal on the grid will result in a negative output. (A circuit of this kind is called a cathode follower, because the cathode voltage tends to follow the voltage changes on the grid. A cathode follower is a useful coupling circuit because it draws practically no current from the preceding stage.)

The signal output from V101B is too small in both voltage and current to supply the control fields of the amplidyne generator. The next step is to couple and amplify the signal voltage.

Coupling to Second Stage

The output of the first stage feeds into a series circuit of resistors R125 and R124 in the grid circuit of V101B from across R123 and R122. Between the two pairs of resistors, a resistance capacitance filter circuit consisting of R119, R120, and R121 and C104, C105, C106, and C107 eliminates the 120-Hertz ripple from the output of rectifier tubes V102 and V103. Synchronizing relay K102 and capacitor C110 (fig. 4-2) between the filter and the grid of V101B are used in the synchronizing operation described later in this chapter.

Cathode follower V101B (fig. 4-3) performs the usual function of coupling the first and second stages while permitting independent design of both stages. The V101B output voltage varies with the first stage output impressed on its grid, changing in a positive direction for a right train error signal and in a negative direction for a left train error signal. V101B output voltage is applied to grid 1 of the second stage paraphase amplifier V105 through R126, R146, and R147 (fig. 4-3).

Second Stage Amplification

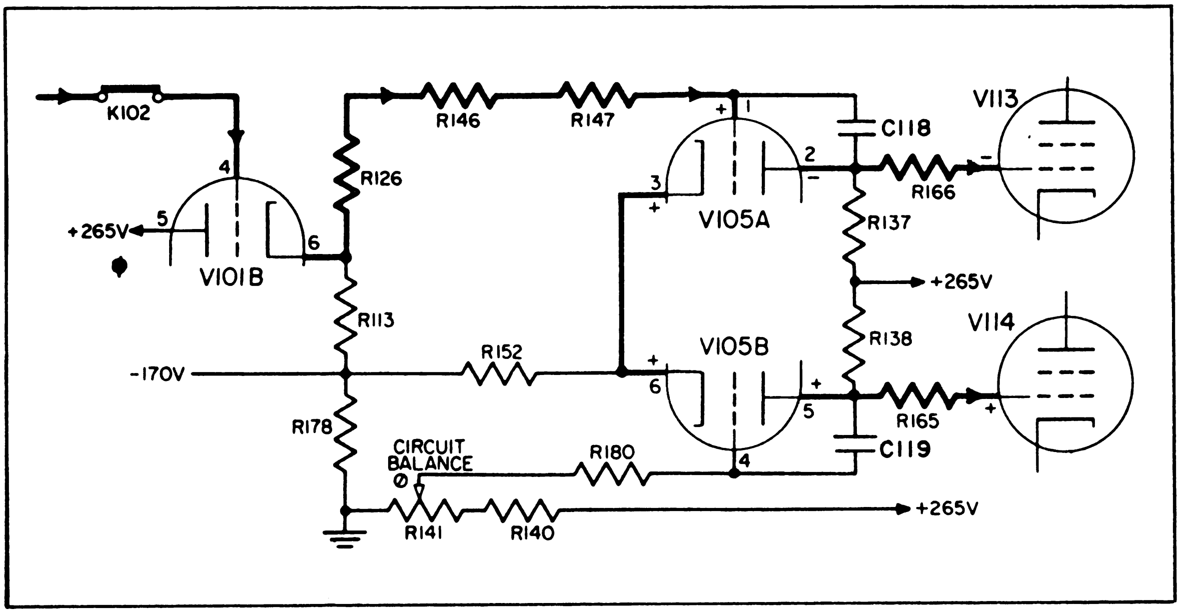
The principal component of the second stage amplifier is tube V105 (fig. 4-3). The top half, V105A, is connected as a conventional amplifier and is controlled by the output of V101B. The output of V105A is taken from plate 2 and applied to the control grid of the third stage output amplifier, tube V113, through grid resistor R166.

Since a right train error signal changes the voltage of grid 1 of V105A in a positive direction, the signal increases the current flow through plate 2. This reduces the plate voltage and results in a negative change of voltage at the control grid of V113. A left train error signal has the opposite effect.

The lower half, V105B, is connected as an amplifier with a fixed grid potential determined by adjusting R141 and a variable cathode voltage. Since the two cathodes of V105 are connected in parallel, the cathode potential in V105B depends upon current flow in V105A. An increase of current flow through plate 2 (right train) changes the cathode potential in a positive direction. In V105B this change has the same effect as a negative change in grid voltage and so reduces the current through plate 5. Similarly, a decrease in current in plate 2 (left train) increases current in plate 5 through grid resistor R165 to the control grid of V114. Since a right train signal decreases current in plate 5, it results in a change of voltage in the positive direction at the control grid of V114; a left train signal has the opposite effect.

Two low-pass filter networks remove ripple voltages from grids 1 and 4 of V105. The grid 1 filter consists of R126, R146, R147, and C118. The grid 4 filter consists of R180 and C119 (fig. 4-3).

To summarize, a right train signal makes the grid of V113 more negative, and the grid of V114 more positive. A left train signal would, of course, have the opposite effect. Although V105 amplifies the signal voltage, it cannot supply enough current for the control windings of the amplidyne generator; therefore, the next step is to amplify the current.



53.57

Figure 4-3.—Second stage of the train amplifier; simplified schematic.

Third Stage Amplification

The principal components of the third stage push-pull current amplifier shown in figure 4-4 consists of two tetrode tubes, V113 and V114. These tubes are connected as conventional amplifiers; V113 supplies current to the F1-F2 control field of the amplidyne, and V114 supplies current to the F3-F4 control field. The operating level of the tubes can be adjusted by potentiometer R177, which controls the cathode potential of both tubes. As indicated in the preceding paragraphs, a right train signal changes the control grid voltage of V113 in the negative direction and that of V114 in the positive direction. It results in light current for the F1-F2 field and heavy current for the F3-F4 field. The heavy current from the F3-F4 control field windings will cause the amplidyne generator to produce an output voltage that will train the mount to the right. A left train signal causes the control grid voltages to be reversed and thus has an opposite effect.

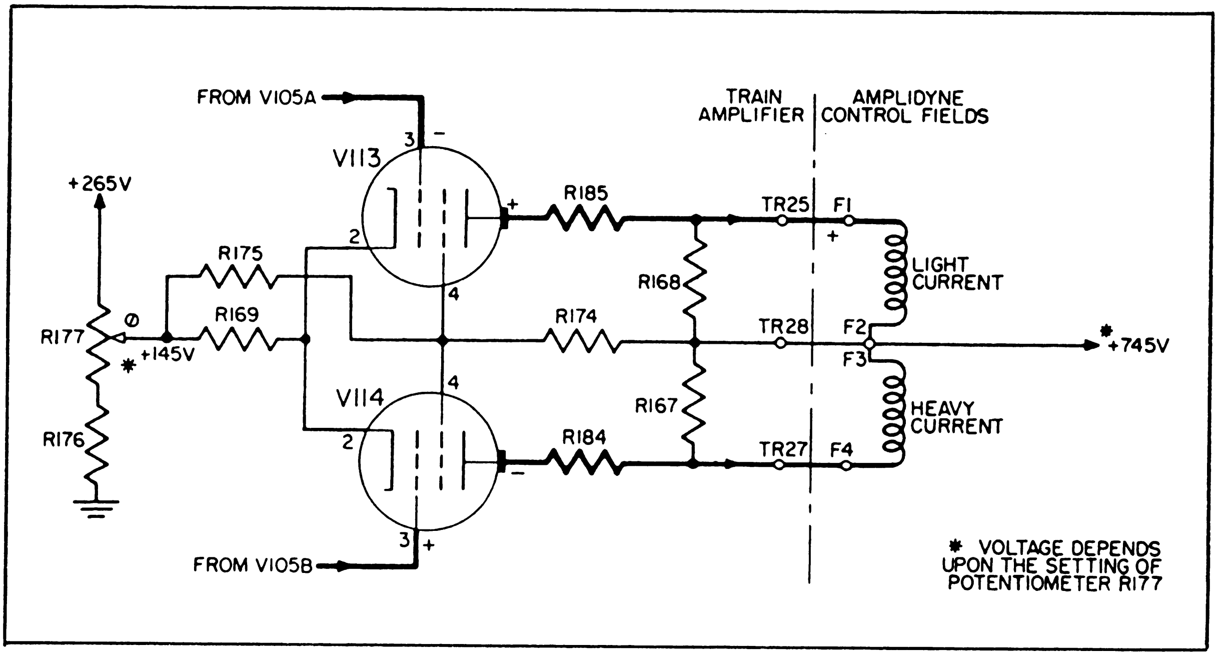
In the power stage, resistors R184 and R185 prevent oscillation in the output of V113 and V114. Thyrite resistors R167 and R168 provide current paths in parallel with the amplidyne control fields. These resistors have a negative temperature characteristic that reduces their resistance when high voltages are applied. Screen grid voltage for V113 and V114 is taken from a voltage divider consisting of R174 and R175.

Circuit Balance

When a zero error signal is transmitted, the two sides of the motor generator (amplidyne) control field must receive equal currents. Once the operating level of V113 and V114 has been fixed by adjusting R177 (see figure 4-4), the current to F1-F2 is fixed because there is a definite voltage at grid 1 of V105A that corresponds to a zero error signal. However, the current to F3-F4 for a zero signal depends upon the operating level of V105B. This level is fixed by adjusting the input to the grid of V105B through the circuit balance potentiometer R141 (see figure 4-3). When R141 is adjusted so that the current is equal in both halves of the control field for a zero error signal, the amplifying circuit is balanced.

Stabilizing Circuit

As the gun mount reaches a position of correspondence with the gun order signal, the drive's output torque must be brought to zero. Because of inertia, however, the mount tends to



* VOLTAGE DEPENDS UPON THE SETTING OF POTENTIOMETER R177

53.58

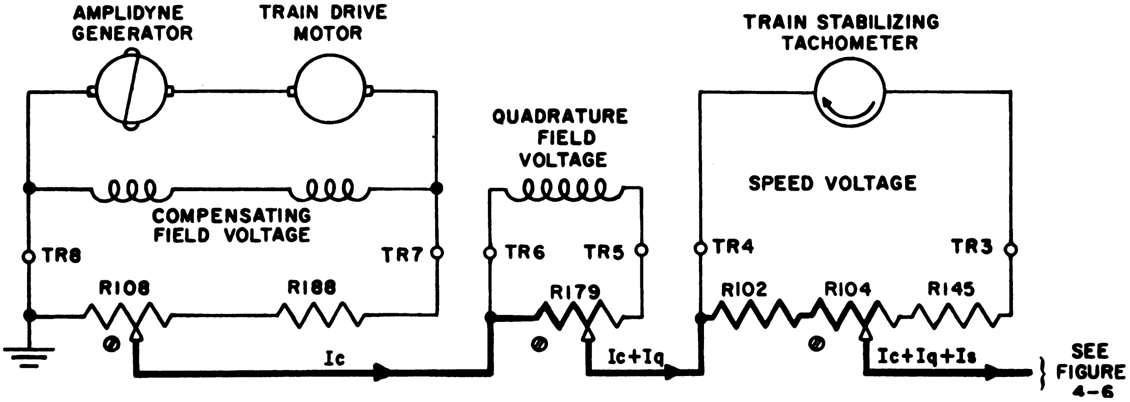
Figure 4-4.—Third stage of the train amplifier; simplified schematic.

overtravel. This overtravel generates an error signal that reverses the direction of mount movement. Repeated overtravels result in oscillations known as hunting. To prevent hunting, three stabilizing voltages are applied to the amplifier. They are the compensating field voltage (Ic), the quadrature voltage (Iq), and the speed voltage (Is). Figure 4-5 shows the source of the three voltages.

The compensating field voltage (Ic) is taken from across the motor generator and drive motor compensating fields. It is proportional to the amount of current drawn by the motor from the motor generator and is used to dampen rapid, medium amplitude mount oscillations. Resistor R188 controls the percentage of compensating field voltage to be applied to the cathode follower V101A. R108 permits adjustment of the voltage. This stabilizing voltage has its greatest effect at the limit of the overswing where the drive motor is trying to reverse its direction of movement and therefore draws a heavy current.

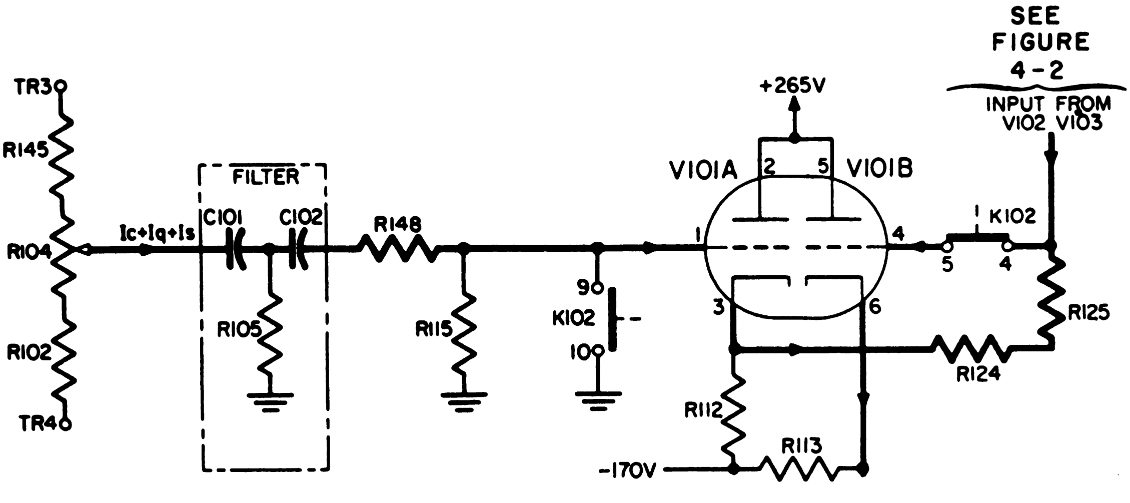
The quadrature field voltage (Iq) is taken from across the quadrature field in the generator. It is proportional to the rate of change in the output voltage and is used to dampen high frequency, small amplitude oscillations that result in chatter and rumble in gear train assemblies. Potentiometer R179 permits adjustment of the voltage to be applied to V101A. The quadrature and compensating field voltages are combined at R179 and sent to potentiometer R104 (fig. 4-5).

The speed voltage (Is) is taken from across the rotor of the stabilizing tachometer. It is proportional to the speed of the mount and is used to prevent low frequency, large amplitude mount oscillations. The stabilizing tachometer, a small dc generator, is driven by the train motor at speeds



53.59

Figure 4-5.—Compensating (Ic), quadrature (Iq), and speed (Is) voltages; simplified schematic.



53.60

Figure 4-6.—Stabilization output circuits; simplified schematic.

proportional to the speed of the mount. Resistors R102 and R145 control the portion of speed voltage to be applied to V101A; potentiometer R104 permits adjustment of the voltage. The three voltages are taken from R104 and sent to the amplifier where they are applied to oppose movement of the mount (fig. 4-5).

Before the stabilizing signal reaches V101A, it passes through a filter consisting of C101, C102, and R105 (see figure 4-6). If the power drive is not hunting, the stabilizing signal is a varying dc. Thus, the capacitors in the filter block the flow of current and grid 1 of V101A is unaffected. If the power drive is hunting, the polarity of the stabilizing signal changes with each oscillation of the mount. Thus, the stabilizing signal becomes a true ac voltage with the same frequency as the hunting frequency and is passed by the filter to grid 1 of V101A.

In normal operation, the gun must swing back and forth with the pitch and roll frequency, but in an opposite direction to the roll and pitch of the ship. Because this frequency is less than hunting frequencies, the capacitors and resistors are chosen to form a high pass filter network that will pass current at hunting frequencies but will block current at the low frequencies resulting from system operation compensation for ship movement.

If the gun has passed the correspondence point and is hunting, the stabilizing voltage will be ac with a frequency high enough to pass through filter capacitors C101 and C102. A right train overshoot changes the grid voltage of V101A to negative, provided it is of short enough duration to pass the filter network. Resistor R115 (fig. 4-6), connected to the grid of tube V101A, acts as a load resistor for the filter network and a voltage bias resistor for the grid. As grid 1 of V101A changes negatively, less current flows to cathode bias resistor R112. This resistor is also part of the V101B grid 4 circuit. The change in current flow through R112 causes V101B grid 4 potential to move in a negative direction reducing the positive effect of the right train signal applied to the same grid circuit by the output of tubes V102 and V103. Since the effect of the stabilizing voltage is to reduce the effect of the error signal as the mount approaches correspondence, it reduces the speed of travel and thereby shortens the next overswing. When the gun passes the correspondence point and starts to swing back under the influence of the left train signal, the stabilizing voltage is reversed and its effect opposes that of the left train signal. Thus, an opposing force is applied to the load in either direction in train, with the result that hunting is effectively stopped.

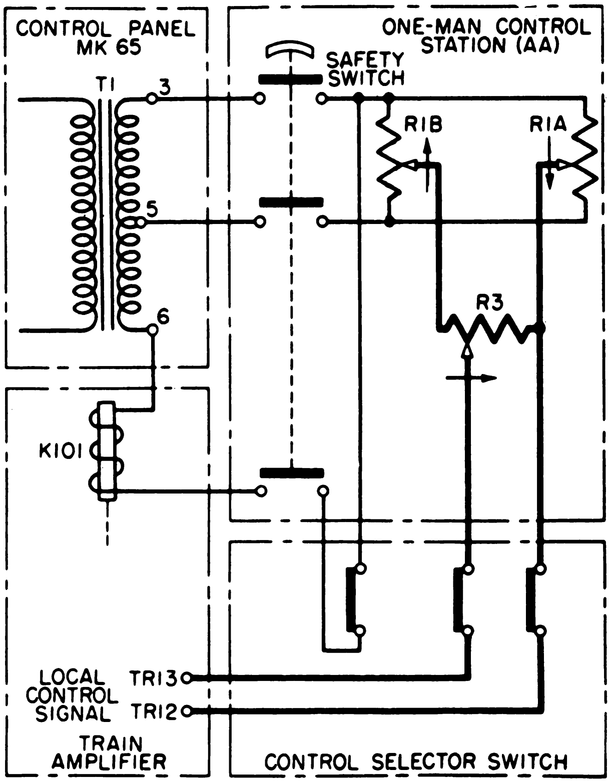
Q5. In which stage of a three-stage amplifier is the signal rectified from ac to dc?

Q6. What are the two primary control components in the third stage of a three-stage amplifier?

Q7. What term describes the motion where a gun mount repeatedly overtravels, resulting in oscillation of the mount?

LOCAL CONTROL CIRCUITS

In local control, the error signal to the amplifier originates at an OMC station on the gun mount. There are two OMC stations for the power drive—local surface and local AA. Only one station can be used at a time. Either one can deliver gun error signals for train and elevation. Figure 4-7 shows the local AA station train circuit.



53.63

Figure 4-7.—Dual potentiometer signals to amp; simplified schematic.

When the safety switch is closed, a voltage is placed across the two potentiometers R1A and R1B, and the local control relay in the train amplifier is energized.

Local Control Signal

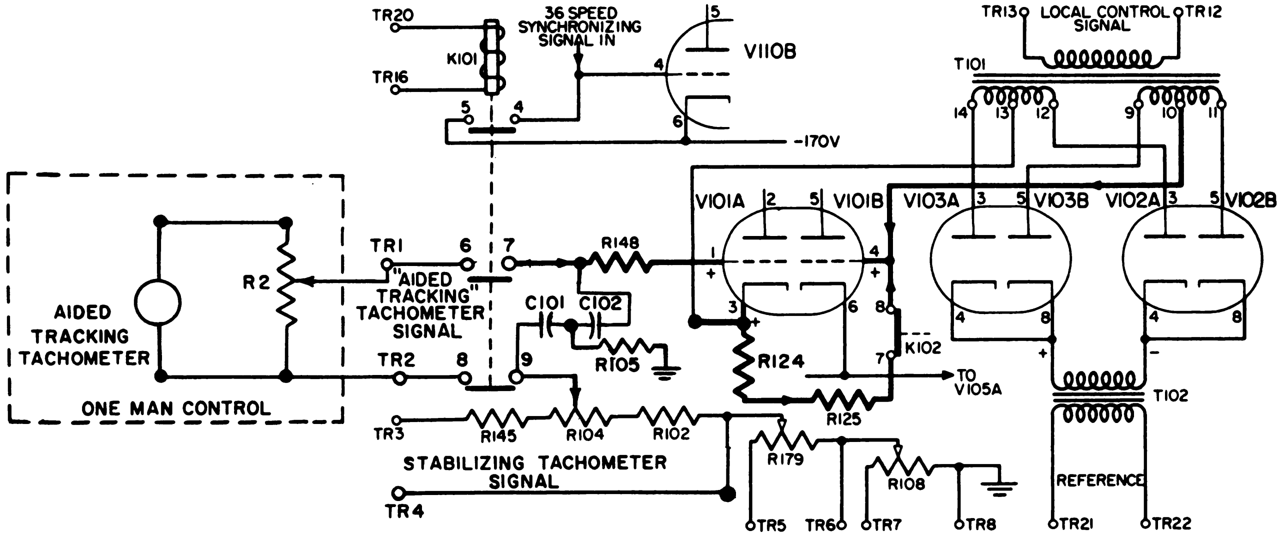
R1A and R1B are a balanced bridge circuit. They furnish the error signal for local control. When the OMC housing is centered, the movable fingers of the potentiometers are also centered, and there is no potential difference between them. When the OMC housing is deflected, the fingers will move in opposite directions along the potentiometer windings. This will cause a potential difference between them, and current will flow through R3. The signal to the amplifier is picked off the adjustable potentiometer, R3. The amount of OMC deflection will determine the magnitude of the signal, and the direction of deflection will determine its phase.

Aided Tracking Tachometer

In addition to the potentiometer signal, a dc voltage is supplied by a tachometer generator in the OMC. The voltage introduced by the aided tracking tachometer aids the potentiometer signal in overcoming mount starting inertia. The tachometer voltage is taken off potentiometer R2, and applied to the amplifier, as shown in figure 4-8.

When K101 is energized, one set of contacts shorts the grid of V110B to its cathode. This keeps K102 from operating and, therefore, keeps the synchronizing circuits disconnected. Another set of contacts of relay K101 connects the aided tracking tachometer to the grid of V101A. Still another set of contacts connects the three stabilizing voltages to the aided tracking voltages.

When the mount is stationary, there is no voltage input to the grid of V101A. If the OMC is deflected in such a direction as to call for right train, the tachometer will generate a positive signal which is coupled to the grid of V101A. The resultant positive voltage change is taken off the cathode of V101A and transmitted to the grid of



53.64

Figure 4-8.—Local control circuits; simplified schematic.

ANSWERS TO QUESTIONS Q5 THROUGH Q7.

A5. First stage.

A6. Two tetrode tubes (V113 and V114).

A7. Hunting.

V101B. As you may remember, a positive signal on the grid of V101B has the effect of a right train signal.

The aided tracking tachometer supplies a signal only while the OMC housing is moving. When the OMC stops (except in its neutral position), the local control signal from the dual potentiometers keeps the mount moving. The local control signal is now applied to the transformer T101 in the amplifier, where it has the same effect as an automatic signal on the principal amplifier circuits.

Stabilizing Voltages

Once the mount starts to move, the stabilizing voltages are applied directly to the grid of V101A, where they oppose the signal voltage. The dominating stabilizing voltage comes from the stabilizing tachometer. The output of this tachometer is proportional to mount speed.

For a right train signal, the negative output of the stabilizing tachometer increases as the mount speed increases, until it balances the effect of the local control signal. No further increase in mount speed is possible, therefore, unless the OMC is moved farther off center to increase the signal voltage. If the OMC is moved back toward its center position, the stabilizing tachometer voltage will exceed the signal voltage. This is equivalent to a left train signal, and will slow the mount down until a balance is reached. In local control, then, the stabilizing tachometer acts as a governor to control mount speed.

Q8. What are the two local control circuits used to drive a gun mount?

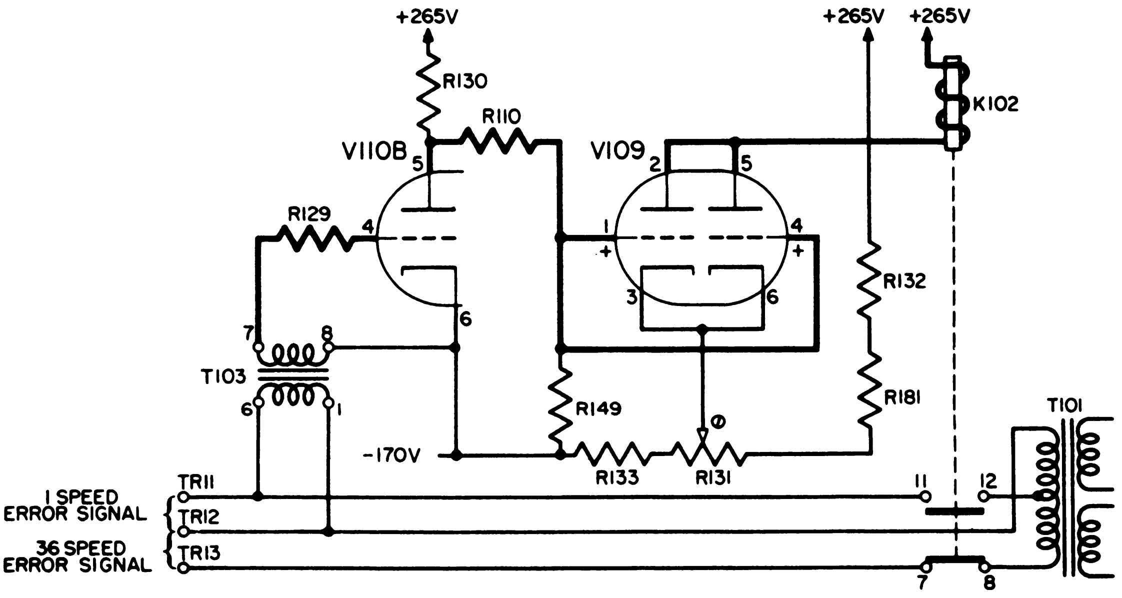
AUTOMATIC CONTROL CIRCUITS

In automatic control, synchros are used to compute and transmit gun error and gun order. To ensure both accuracy and speed, ordnance synchro systems are usually subdivided into a coarse (1-speed) and a fine (36-speed) circuit. The details of operation and maintenance of synchros and synchro circuits were spelled out in chapter 2 of this text. The synchro system used in the Mk 35 power drive is typical of those with which you are familiar.

When the mount is more than about 2° out of correspondence, the amplifier receives the 1-speed error signal, but not the 36-speed signal. A synchronizing relay is used to select the signal to be applied to the amplifier.

Synchronizing Relay K102

Figure 4-9 shows synchronizing relay K102, and the circuit that controls its action (and thus



53.61

Figure 4-9.—Energizing synchronizing relay; simplified schematic.

determines whether the fine or coarse signal will be sent to the amplifier). When the relay is energized, the mount is in coarse control, and the 1-speed error signal is transmitted through contacts 11 and 12. When the relay is deenergized, contacts 7 and 8 are closed, connecting the fine signal to the amplifier. This is the condition shown in figure 4-9.

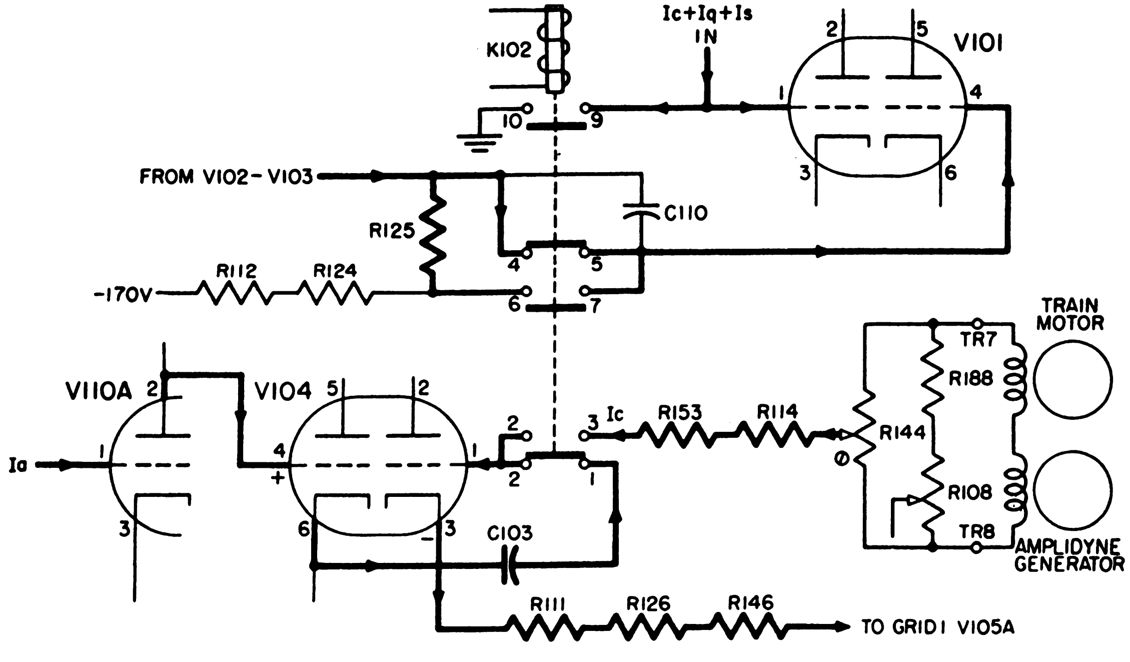
In fine control, V110B is conducting heavily, and V109 only slightly—not enough to actuate the synchronizing relay.

When the gun is approximately 2° out of synchronization, the 1-speed signal voltage has increased to a point where the operation of V110B can be affected. The 1-speed signal is applied to transformer T103 from terminals TR11 and TR12 of the train amplifier. The secondary of T103 is connected to the grid and cathode of V110B. The positive swing of an incoming coarse ac signal will have little effect on the tube because it is already passing near its maximum current. During each negative swing of the input signal, tube current will decrease. As the average tube current decreases, the average plate potential rises.

Tube V109, which has been conducting only slightly, now receives the positive signal from V110B on its grid. This increases the current flow through the tube and through the synchronizing relay in its plate circuit. When the coarse signal is of sufficient magnitude, K102 will operate.

When relay K102 is energized by the coarse control signal (see figure 4-10), the mount is at least 2° from correspondence. In this condition the three stabilization voltages are not required, and contacts 9 and 10 of K102 will short them to ground. In their place, a voltage proportional to the current drawn by the drive motor and generator is used. It is drawn from adjustable potentiometer R144, and its output goes through V104 to the grid of V105A. V105, you remember, controls the two tubes in the third (power) stage of the amplifier.

In fine control, the signal voltage is taken from the top of R125, across contacts 4 and 5 of the



53.62

Figure 4-10.—Effect of relay K102 on stabilization; simplified schematic (shown deenergized).

ANSWER TO QUESTION Q8:

A8. Local surface and local AA.

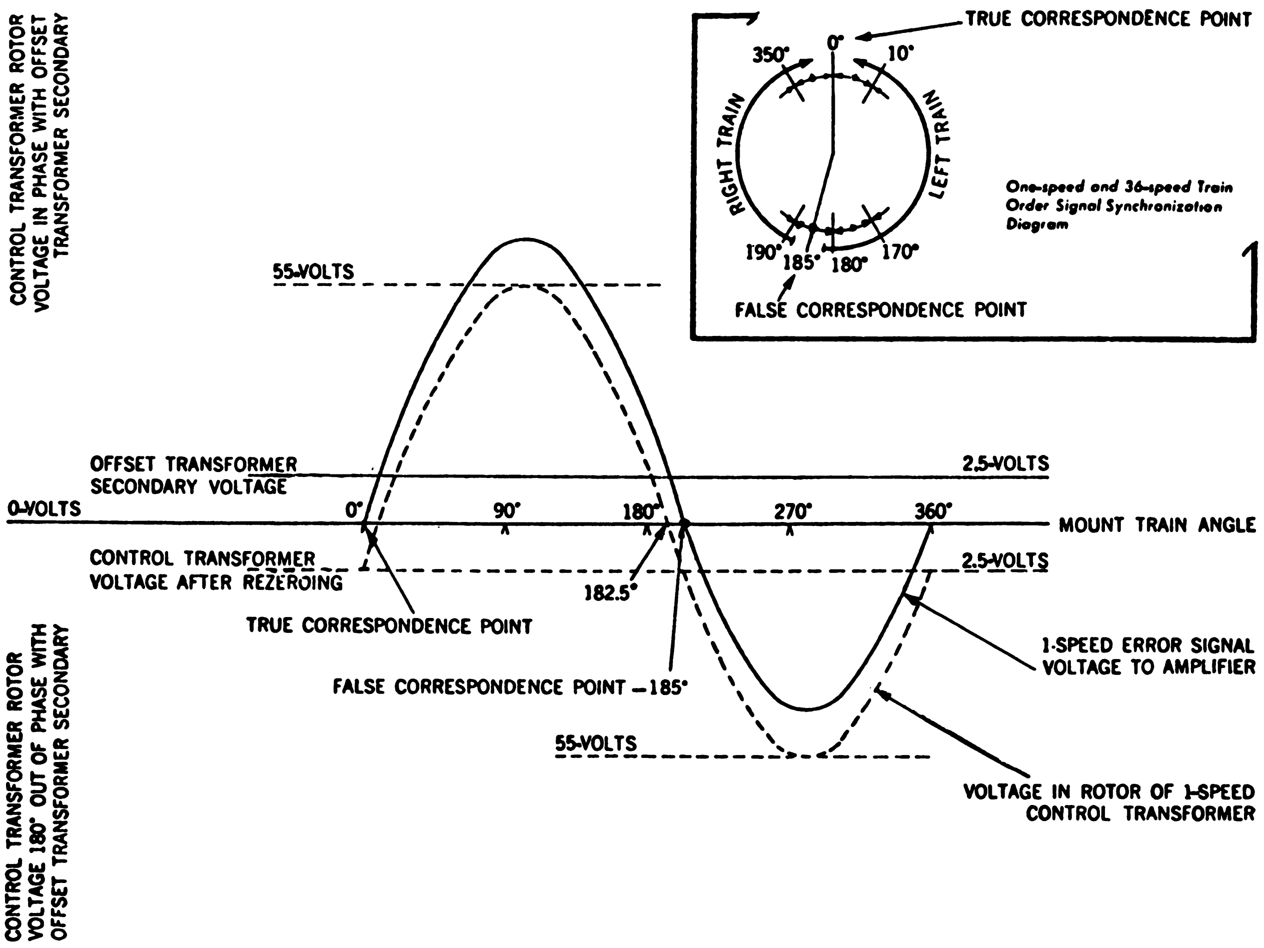
synchronizing relay, and applied to the grid of V101. In coarse control, K102 opens contacts 4 and 5, while it closes 6 and 7. This causes the signal to be taken from a point on the voltage divider formed by R125, R124, and R112, rather than directly from the input. Abrupt changes in input voltage are transmitted to V101 directly through C110, rather than just through the voltage divider. This makes the system more responsive, and helps to prevent overtravel.

Offset Transformer

The 1-speed error signal cannot be used directly since it has a false correspondence point 180° from the true correspondence. At this point, the synchro rotor is at right angles to the magnetic field and the induced error signal voltage is zero, just as it is at true correspondence. For a small distance each side of the false correspondence point, there is a dead space in which the 1-speed error signal is too weak to actuate the synchronizing relay. If the control-selector switch were shifted to AUTO with the mount in this dead space, the 36-speed signal would run it to the false correspondence point and hold it there.

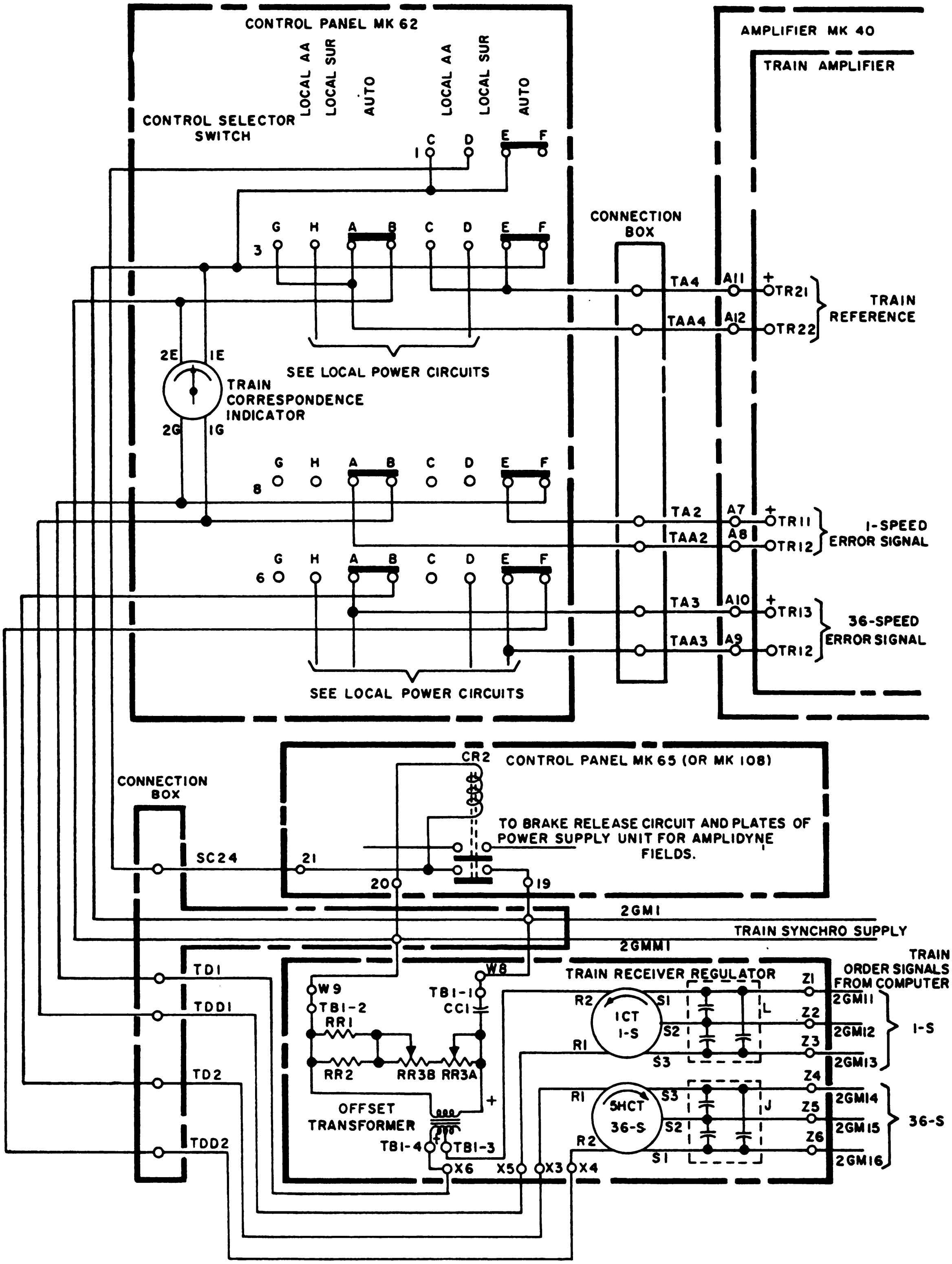
To avoid this difficulty, the error signal is modified and the 1-speed train control transformer is zeroed in such a manner that the false correspondence is shifted about 5°. With the false correspondence point 185° from the true correspondence, the 36-speed signal runs the system out of the dead space instead of centering it there (see figure 4-11).

The 36-speed error signal also has a false correspondence point (5° from true correspondence), but this signal has no dead space—so the slightest movement of the signal or


CONTROL TRANSFORMER ROTOR VOLTAGE IN PHASE WITH OFFSET TRANSFORMER SECONDARY
CONTROL TRANSFORMER ROTOR VOLTAGE 180° OUT OF PHASE WITH OFFSET TRANSFORMER SECONDARY
TRUE CORRESPONDENCE POINT
0°
10°
350°
RIGHT TRAIN
LEFT TRAIN
190°
185°
180°
170°
FALSE CORRESPONDENCE POINT
One-speed and 36-speed Train Order Signal Synchronization Diagram
55-VOLTS
OFFSET TRANSFORMER SECONDARY VOLTAGE
2.5-VOLTS
0-VOLTS
0°
90°
180°
270°
360°
MOUNT TRAIN ANGLE
CONTROL TRANSFORMER VOLTAGE AFTER REZEROING
2.5-VOLTS
182.5°
TRUE CORRESPONDENCE POINT
1-SPEED ERROR SIGNAL VOLTAGE TO AMPLIFIER
FALSE CORRESPONDENCE POINT — 185°
55-VOLTS
VOLTAGE IN ROTOR OF 1-SPEED CONTROL TRANSFORMER

53.270

Figure 4-11.—Modification of 1-speed train order signal; phase diagram.



53.211

Figure 4-12.—Signal circuits to amplifier train system; AUTO control.

the mount will throw it off balance and start it in one direction or the other.

The 1-speed error signal is modified by adding to it a voltage from the secondary winding of an offset transformer. As shown in figure 4-12, the secondary winding of the offset transformer is inserted in series with the R2 lead of the train 1-speed synchro control transformer. The polarity signs of figure 4-12 indicate that 2-1/2 volts ac potential in the transformer secondary winding is equivalent to a signal calling for about 2-1/2° of right train. Consequently, for the error-signal voltage at train amplifier terminals TR11 and TR12 to drop to zero when the mount is in correspondence with the 1-speed train order signal, the stator of the 1-speed train control transformer (CT) must be shifted 2-1/2° in such a direction that an error-signal voltage is induced in the rotor windings calling for 2-1/2° of left train. By rezeroing the 1-speed control transformer, the false correspondence point is shifted about 5° because the addition of the offset transformer voltage moved the false correspondence point 2-1/2°, and the rezeroing of the 1-speed control transformer shifted it another 2-1/2° in the same direction, making a total shift of 5°.

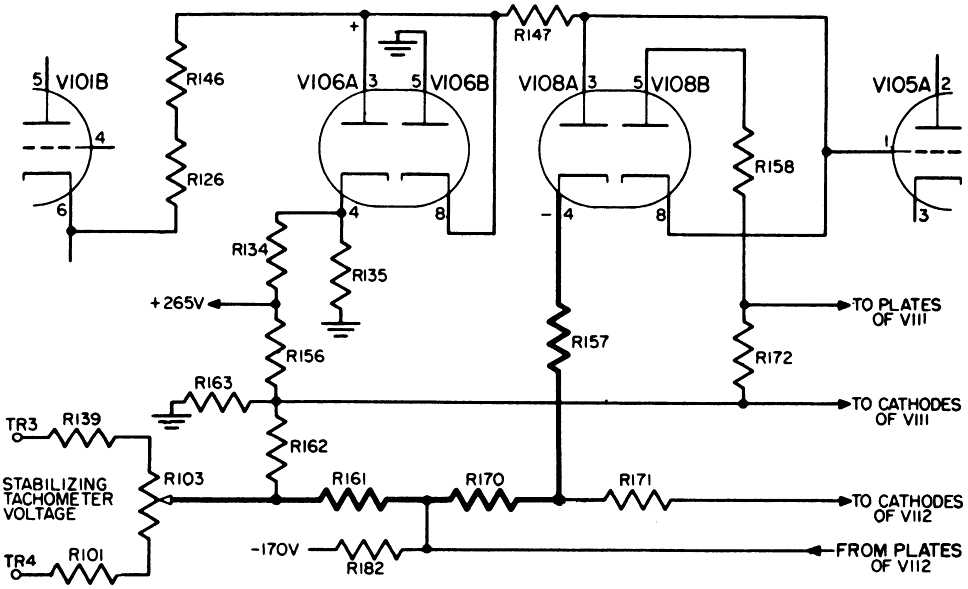
If the mount is shifted to automatic and is 180° from true synchronization, the modified error signal causes a phase difference between the signal and reference voltages in the first stage of the amplifier. This phase difference causes the mount to train in the correct direction for true synchronization.

To sum up the action of the offset transformer, it can be stated that it effectively establishes a single zero position for the rotor of the 1-speed control transformer, eliminating the possibility of 180° error in the system.

POSITION, SPEED, AND CURRENT-LIMITING CIRCUITS

The amplifier circuits are capable of generating gun train and elevation signals which, if they were not limited, could damage the power drive components. The signal limiter tube V106 is shown in figure 4-13. It keeps excessive train signals from reaching V105A.

Plate 3 of V106A and cathode 8 of the V106B are connected between R146 and R147 on the line leading to grid 1 of V105A. When there is no train signal from V101B, this point between the resistors is positive with respect to ground. Cathode 4 of V106A is connected to a point between voltage divider resistors R134 and R135; this point is more positive than plate 3 of V106A. When the right train signal exceeds a certain amplitude, plate 3 will become positive with respect to cathode 4; V106A will then conduct,



53.65

Figure 4-13.—Speed limit circuits; simplified schematic.

and thus limit the right train signal. The other half of limiter tube V106B will act in a similar manner to provide limiting action on the negative left train signals.

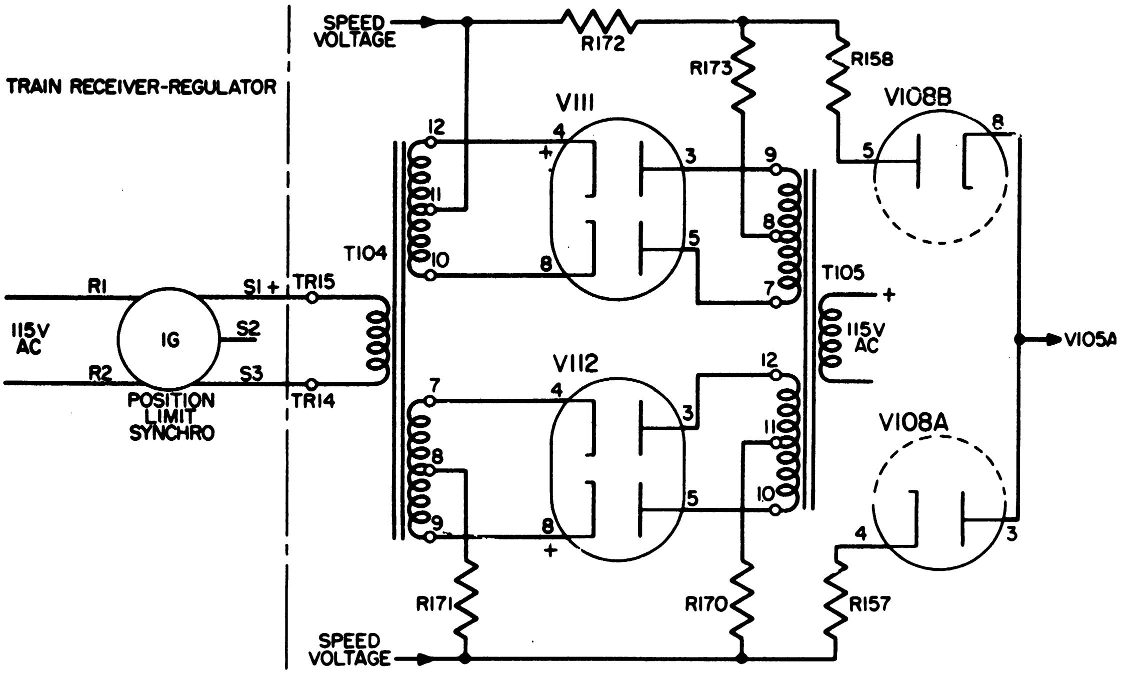
The operational speed of the mount is limited by a voltage, proportional to speed, taken from the tachometer. This voltage is applied to the amplifier at terminals TR3 and TR4, and reduces the effect of the gun train signals.

Cathode 4 of V108A is tied, via R157 and R170, to a point of negative potential on the resistor network made up of R156, R163, R162, R161, and R182. The output of V112 is a pulsating direct current, drawing current through R170 and causing a voltage drop across it, thus raising cathode 4 of V108A to a relatively high positive potential. When there is no train signal, plate 3 of V108A is less positive than cathode 4, and V108 will not conduct.

When the mount trains to the right, the stabilizing tachometer introduces a negative voltage at a point between R161 and R162. As a result, all points on the voltage divider will shift in a negative direction. The negative shift becomes greater as the mount speed increases. If the right train signal calls for a speed greater than the desired limiting speed, this shift in potential will be sufficient to make cathode 4 of V108A negative with respect to the plate, and this half of the tube will conduct. When V108A conducts, it draws current from the line that carries the right train signal. This action decreases the signal at grid 1 of V105A; the mount does not follow at the speed called for, and lags behind the gun director (in automatic) or the one-man control (in local). V108B, in conjunction with V111, acts in a similar manner to limit the negative left train signal on the grid of V105A. As the mount lags behind because its speed is limited by V108, the train signal tends to increase. The signal on the grid of V105A does not increase, however, because of the limiting action of V106.

The position of the mount is also electrically limited to keep the power drive from slamming it against the mechanical limit stops. As the mount approaches one of the stops, it moves the rotor of a synchro generator in the limit stop mechanism. This synchro generator produces a limit signal that gets stronger as the mount approaches the mechanical stops.

Now, let us assume that the mount is approaching the mechanical limit while training to the right. A signal from the limit synchro generator appears across the primary of T104 (fig. 4-14). On this particular half cycle the plate reference voltage at T105 and plate 5 of V112 will be positive, and this section of the tube will



53.66

Figure 4-14.—Position limit circuits; simplified schematic.

conduct. The rotor of the limit signal generator is excited by the same 115 ac source as the primary of T105. Consequently, for this particular half cycle, the limit signal on cathode 8 of V112 will be positive. This reduces the conduction of the lower section of V112, and reduces the current through R170. This, in turn, makes cathode 4 of V108A more negative.

If the mount is training at maximum speed as it approaches the limit, the combined effect of the speed signal and the limit signal is strong enough to cause an immediate reduction in speed. As the speed drops, the strength of the speed signal decreases and that of the limit signal increases until a point is reached at which the limit signal exceeds the right train signal. The resultant signal on grid 1 of V105A has the effect of an electrical brake, and the mount stops. Since the limit signal depends only on mount position, the mount will always stop at the same point, no matter how fast or how slow it approaches the limit.

As the mount approaches its left limit, the signal from the limit synchro reduces the current drawn by rectifier tube V111. V111 then acts to bring the mount to a stop at the left limit, as V112 does at the right limit.

The current drawn by the train motor must be limited to prevent sudden changes in motor speed which would be dangerous to personnel and equipment. To do this, the error signal on grid 1 of V105A is modified by V107. The operation of V107 is similar to that of the speed and position limiter V108.

Q9. What is the purpose of using current-limiting circuits in gun power drives?

MOTOR FIELD CONTROL CIRCUITS

These circuits supply the excitation voltages for the drive motor fields. The current flow through the field windings must remain constant. A small change would result in a relatively large change in motor speed.

The maximum speed of the elevation drive motor is 1500 rpm, with a corresponding elevation rate of 24° per second. This speed is obtained with a field excitation of 1.4 amps. Speeds in excess of 1500 rpm are obtained by the train drive motor by a reduction of field excitation. This reduction of field excitation reduces the counter electromotive force (cemf) generated by the motor, and thus increases motor speed. The maximum train rate is 30° per second.

Figure 4-15 shows the elevation motor field control circuit. (The circuit for the train motor is similar, except for its higher speed.) Tubes V306 and V307 are connected to the secondary of transformer T2 in such a manner that they provide full-wave rectification of the drive motor field excitation current. The dot in the tubes indicates that they are gas filled. A gas-filled triode is called a thyratron. The grid-voltage determines the plate voltage at which the thyratron will fire and begin to conduct. Once the tube starts to conduct, the gas ionizes and becomes effectively a short circuit through the tube. The grid then loses control of the tube until the gas de-ionizes. With alternating current on the plate, this will happen during alternate half cycles.

The grid bias of V306 and V307 is controlled by V305. The current in the motor field, F1-F2, flows through cathode resistors R316 and R338, and thus affects the bias of V305. An increase in current flow will cause the cathode to swing in a negative direction, resulting in more current flow through V305. This reduces the plate potential. The plate potential is coupled to the grid of V306 through R314, R323, and R325; and to the grid of V307 through R314, R324, and R326. Thus, these grids are controlled, indirectly, by the current flow through the field of the drive motor. In effect, what we are doing is taking continuous measurements of the field current, and applying any change to the source of the current, V306 and V307, to cancel the change.

Winding K301 is the coil of relay K301 which deenergizes the power supply unit and applies the brake if we lose the drive motor field excitation.

Q10. On the 3″/50 RF gun mount, what is the maximum speed of travel in train?

MAINTENANCE

There are two kinds of maintenance procedures—planned maintenance and corrective maintenance. The planned maintenance system (PMS) provides a standard means for performing maintenance on your equipment. PMS actions are the minimum required to maintain equipment in a fully operable condition within specifications.

If performed according to schedule, these maintenance actions will prevent future equipment failures which might otherwise result in repeated corrective maintenance actions. Corrective maintenance is that maintenance that is performed when casualties occur. The problems are usually of such a nature that they are not easily located or repaired.

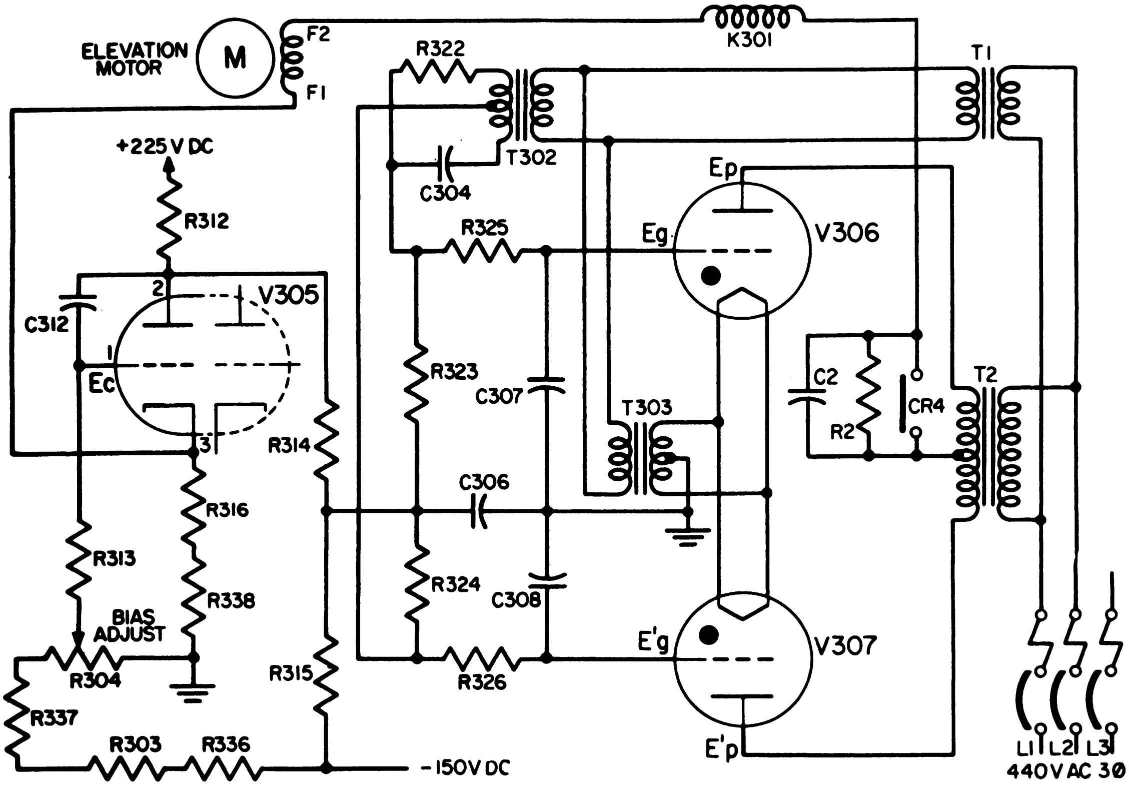
SUPERVISION

As a GMG1, you will be considered the expert in your specialty. You will be required to teach the basic skills of maintenance and safety as it relates to ordnance equipment.

REPAIR

When casualties occur in your equipment, you will need to follow a logical, step-by-step procedure of casualty analysis to troubleshoot them. This procedure is basically one of eliminating areas where the fault does not lie, starting with large areas and gradually narrowing to smaller and smaller segments until the trouble is detected. Follow along as we simulate a problem from beginning to end.

Suppose that, during a transmission check one day, you discover that one of your twin 3"/50 mounts moves sluggishly in train. Furthermore,



53.67

Figure 4-15.—Elevation motor field control circuits; simplified schematic.

ANSWERS TO QUESTIONS Q9 AND Q10.

A9. Prevent damage to power drive components.

A10. 30° per second.

the sluggishness is more apparent with a left train signal than with a right train signal. Also, let us assume that this condition is observed while the gun is in automatic control. It is obvious that one or more of the following units is not operating properly.

1. The synchros that originate the error signals
2. The train amplifier
3. The train amplidyne

However, these three possibilities cover a large area. Let us start our elimination process with the synchros, by switching the selector switch to a local station. Synchro signals, you know, are not used in local control. Upon switching to local, however, you find that you still have the original trouble. That eliminates the synchros as a possible source of trouble.

The next item on our list of possibilities is the train amplifier. As you remember, the last stage (power stage) of the amplifier is connected to the control fields of the amplidyne generators. We can check the output of the amplifier, then, by measuring the voltage drop across amplidyne fields F1-F2 and F4-F3. We measure the voltage drop across the F4-F3 field with a 5° right train signal, and the voltage drop across the F1-F2 field with a 5° left train signal. This check reveals that the voltage drop across the F1-F2 field is much smaller than across the F4-F3 field. Now we have established that the casualty is somewhere in the train amplifier.

A look at the circuits in the train amplifier shows us that the trouble must be in the circuits associated with V106, V107, V108, V111, or V112 since these circuits control the right or left train signal limiting. (If the trouble had been in any of the other circuits, we would have found identical symptoms on both right and left train signals.)

Now we must examine each of the possible casualties.

If V106, V107, or V108 were inoperative, there would be no signal limiting, and consequently mount train would not be sluggish.

If either half of V106, V107, or V108 were shorted, the mount would be sluggish on both right and left train signals.

If V112 were inoperative, cathode 3 of V108A would become negative because of the loss of circulating current through R170. This would limit right train signals more than left train signals.

If V111 were inoperative, plate 5 of V108B would become positive because of the loss of circulating current through R172. This would limit left train signals more than right train signals and could cause our trouble.

The thing to do now is to check the voltage at plate 5 of V108B. In measuring the voltage at plate 5, we find it to be positive. This definitely determines that V111 is not operating properly. All that is left to do is to check the tube and replace it with a new one.

Before we secure, however, we should check balance adjustment R141 and speed adjustment R103 to see if readjustment is necessary.

Q11. What are the two basic types of maintenance procedures?

SAFETY

The primary reason for the quantity of information available on safety precautions is the need to prevent accidents. Not only is there a loss of time involved with accidents, but there could be an accompanying loss of either equipment, material or, in extreme cases, life itself.

As a leading Gunner's Mate, your responsibilities regarding electrical safety may be grouped into two basic areas.

1. Your responsibilities concerning the GM group or weapons system. These responsibilities include ensuring that all personnel in gun gangs are aware of and observe all shipboard safety precautions, especially those regarding electrical and electronic safety.

2. Your responsibilities concerning all other types of safety precautions. This responsibility includes the proper indoctrination and on-going education of your subordinates regarding all types of electrical and electronic safety as it relates to your assigned equipment.

ELECTRIC SHOCK

Electric shock may cause burns of varying degrees, cessation of breathing and unconsciousness, ventricular fibrillation or cardiac arrest, and death. If a 60-Hertz alternating current is passed through a person from hand to hand or from hand to foot, the effects when current is gradually increased from zero are as follows:

1. At about 1 milliampere (0.001 ampere), the shock will be felt.
2. At about 10 milliamperes (0.01 ampere), the shock is severe enough to paralyze muscles and a person may be unable to release the conductor.
3. At about 100 milliamperes (0.1 ampere), the shock is usually fatal if it lasts for 1 second or more. It is important to remember that fundamentally, CURRENT, rather than VOLTAGE, is the criterion for shock intensity.

It should be clearly understood that body resistances will vary. That is, if the skin is dry and unbroken, body resistance will be quite high—from 300,000 to 500,000 ohms. However, if the skin becomes moist or broken, body resistance may drop to as low as 300 ohms. Thus a potential as low as 30 volts could cause a fatal current flow. Therefore, any circuit with a potential in excess of this value must be considered dangerous. It should be noted at this point that taking an intentional shock is prohibited by Navy regulation.

Q12. What is the most likely effect to a person who receives an electrical shock of approximately 100 milliamperes (0.1 ampere) which lasts for a period of one second or longer?

CARE OF SHOCK VICTIMS

Electric shock is a jarring, shaking sensation resulting from contact with electrical circuits or from the effects of lightning. The victim usually experiences the sensation of a sudden blow, and if the voltage is sufficiently high, unconsciousness. Severe burns may appear on the skin at the place of contact; muscular spasm can occur, causing a person to clasp the apparatus or wire which caused the shock and be unable to turn loose. Electric shock can kill its victim by stopping the heart or by stopping breathing, or both. It may sometimes damage nerve tissue and result in a slow wasting away of muscles that may not become apparent until several weeks or months after the shock is received.

The following procedures are recommended for rescuing and caring for shock victims.

1. Remove the victim from electrical contact at once, but do not endanger yourself. This can be done by: (1) throwing the switch, if it is nearby; (2) using a dry stick, rope, leather belt, coat, blanket, or any other nonconductor of electricity.
2. Determine whether the victim is breathing. If so, lay the victim in a comfortable position and loosen the clothing about the neck, chest, and abdomen so breathing is unhampered. Protect the patient from exposure to cold; remain watchful.
3. Keep the victim from moving about. After a shock, the heart is very weak, and any sudden muscular effort or activity on the part of the patient may result in heart failure.
4. Do not give stimulants or opiates. Send for a medical officer at once and do not leave the patient until adequate medical care is available.
5. If the victim is not breathing, it will be necessary to apply artificial respiration without delay, even though the patient may appear to be lifeless.

For more information on general safety precautions for electricity and electronics, refer to chapter 5 of OPNAVINST 5100.19.

SUMMARY

The purpose of this chapter was to enable you to better understand the function of the control equipment associated with the amplidyne power drive.

Initially, we discussed the fundamentals of electron tubes in the amplidyne equipment. We explained the operational functions of the train amplifier circuit, the local control circuits, and the automatic control circuit. Briefly discussed were maintenance supervision, repair, and

ANSWER TO QUESTION Q11.

A11. Planned and corrective.

electrical safety. For more detail on the subjects covered in this chapter, you will need to consult the reference materials listed at the end of this chapter and specific equipment OPs and ODs.

REFERENCES

The following reference materials were used to develop the information presented in this chapter.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

Navy Electricity and Electronics Training Series (NEETS), Module 6, *Introduction to Electronic Emission, Tubes, and Power Supplies*, NAVEDTRA 172-06-00-82, Naval Education and Training Program Development Center, Pensacola, Fla., 1982.

Navy Electricity and Electronics Training Series (NEETS), Module 8, *Introduction to Amplifiers*, NAVEDTRA 172-08-00-82, Naval Education and Training Program Development Center, Pensacola, Fla., 1982.

3-Inch 50-Caliber Twin Gun Mount, NAVSEA OP 1753, Second Revision, Naval Sea Systems Command, Washington, D.C., Feb 1968.

Navy Safety Precautions for Forces Afloat, OPNAVINST 5100.19, Department of the Navy, Office of the Chief of Naval Operations, Washington, D.C., 1983.

ANSWER TO QUESTION Q12.

A12. Death.

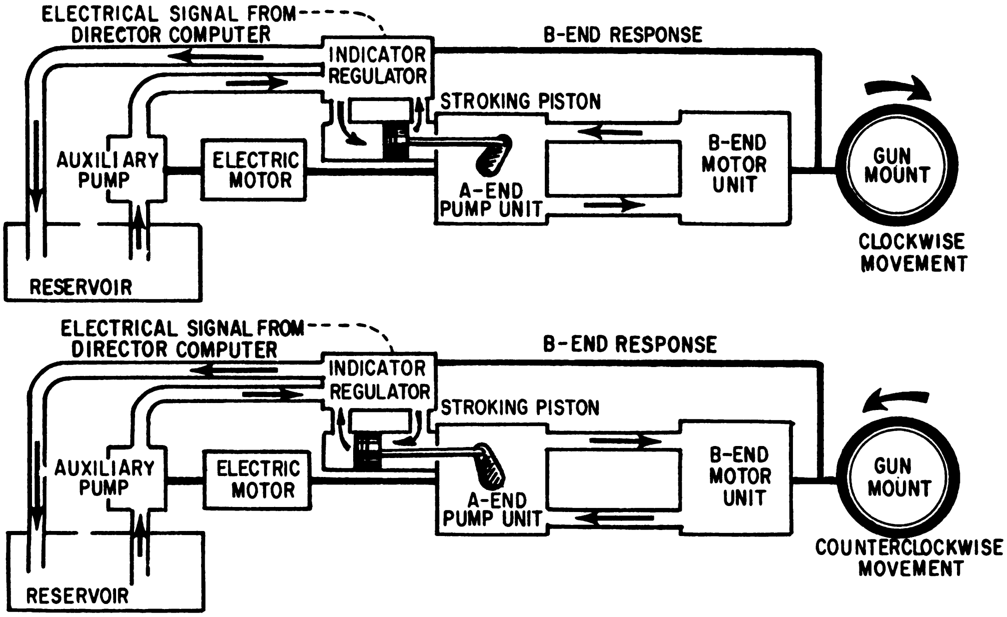
CHAPTER 5

HYDRAULIC POWER DRIVES

Hydraulic power drives have been used with ordnance equipment for many years. Proof of their wide range of effectiveness is the fact that they have been used to train and elevate nearly all calibers of guns from 40-mm to 16-inch turrets. In addition, hydraulics is used to position and control such other ordnance equipment as rocket launchers, missile launchers, ammunition hoists, hoist cradles, rammer assemblies, empty case ejectors and extractors, and breech mechanisms.

We learned from our study of hydraulics in *Fluid Power*, NAVPERS 16193, that one of the principal advantages of a hydraulic system over an all-electric system is its ability to handle larger loads with uniform and flexible control despite rapid variations of the load. Figure 5-1 is a simplified block diagram of a hydraulic power drive system. The indicator regulator receives an initial electrical signal from the director-computer, compares it to the existing mount position, and sends an error signal to the hydraulic mechanism in the regulator. The hydraulic control mechanism controls the flow to the stroke control shaft that positions the tilt box in the A-end. The A-end, which is a variable displacement pump, is driven at a constant speed by the electric motor. The output of the A-end pump is controlled by the amount of tilt on the tilting box. The tilt controls the volume and direction of fluid pumped to the B-end. Through mechanical linkage, the A-end output shaft moves the gun in the direction of the signal. The operation of the hydraulic power drive on each system will not be described in this manual; only system components will be addressed.

In this chapter, we will discuss several hydraulic power drive installations. The systems selected for specific study are used to control the



194.244

Figure 5-1.—Operation of the hydraulic power drive.

movements of the 5"/38 twin gun mount, the 5"/54 Mk 42 Mods 9 and 10 gun mounts, the 5"/54 Mk 45 Mod 0 gun mount, and the 16-inch turrets.

HYDRAULIC TERMS AND PURPOSE

The following is a list of commonly used hydraulic terms and a review of some of the basic hydraulic mechanisms.

A-END: Variable delivery pump. Device which converts mechanical energy to hydraulic energy. Normally driven by a constant-speed electric motor, and provides continuously variable control of speed and direction of output

ACCUMULATOR: Device for storing hydraulic fluid under pressure. Accumulators function to (1) store hydraulic fluid under pressure to supplement pump output during times of peak demand; (2) smooth out surges and pulsations; and (3) meet low-capacity demands without operation of high-capacity pump (except intermittently to charge accumulator)

B-END: Hydraulic motor. Device for converting fluid energy into mechanical energy.

BUFFER: Mechanism used to retard or bring moving equipment to a smooth stop.

CAB UNIT (Combination A-end and B-end): A-end and B-end which are located in the same housing and are separated by a valve plate.

DASHPOT: Device used to cushion the last portion of stroke and prevent metal-to-metal contact of pistons and plungers when they reach their ends of travel.

DUMP VALVE (solenoid operated): When electrically actuated by a solenoid, this valve dumps hydraulic fluid trapped in an accumulator system.

FLASH POINT: The temperature at which a substance, such as fluid, will give off a vapor that will flash or burn momentarily when ignited.

FLOW CONTROL VALVE: Valve which maintains a preset rate of flow regardless of pressure variations.

GLOBE VALVE: Manually operated valve that controls the flow of fluid by means of a plug, ball, or disk which can be raised from, or lowered into, a valve seat.

INHIBITORS (often called ADDITIVES): Chemicals added to hydraulic fluid to improve its ability to retard corrosion and foaming and to resist oxidation.

OXIDATION: Chemical change in hydraulic fluid caused by oxygen which combines with the fluid during high temperature operation.

RELIEF VALVE: Valve which limits the maximum pressure applied to that portion of a hydraulic system to which it is connected.

UNLOADING VALVE: Valve used in accumulator power drives which directs pump output to the accumulator or to tank, according to system demand.

Q1. What type of pump is the A-end?

Q2. What is the purpose of a buffer?

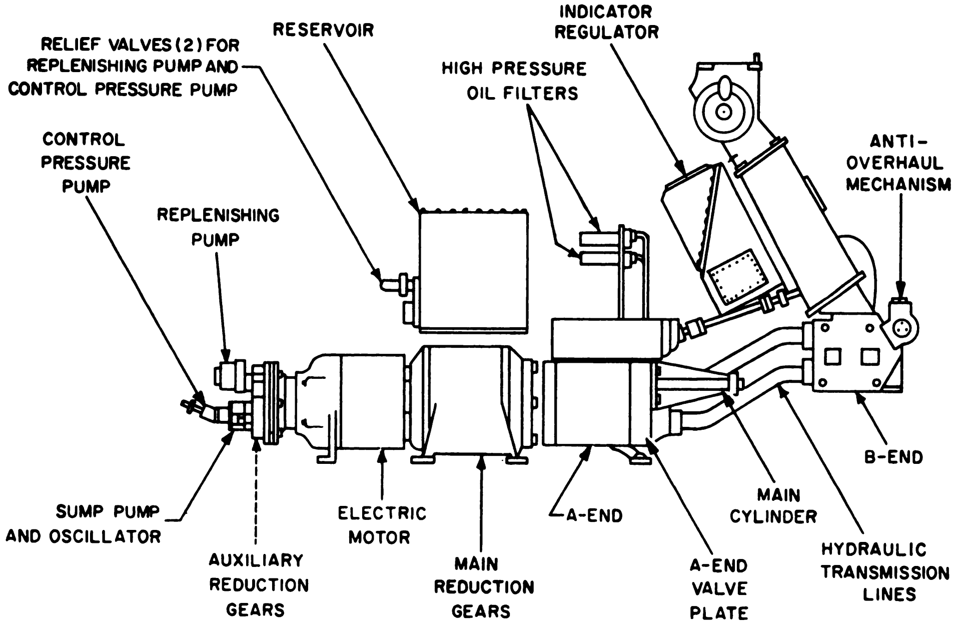
5"/38 TWIN GUN MOUNT POWER DRIVE

Two separate hydraulic installations are used to control the 5"/38 gun mount in train and elevation. These systems differ only in size and minor detail, so only the train power drive will be described.

GENERAL DESCRIPTION

The basic components of the train power drive are shown in figure 5-2. The electric drive motor is constructed with drive shafts at both ends. The forward shaft drives the A-end pump through reduction gears. The after shaft is coupled through reduction gears to the auxiliary pumps.

The ports in the A-end valve plate are connected to like ports in the B-end valve plate by large copper pipes. Oil pumped by the A-end causes rotation of the B-end. Output of the B-end is connected by shafts and gears to the training circle of the mount.



53.69

Figure 5-2.—5"/38 train power drive.

Let us examine each major component in detail to understand its construction and operation.

ELECTRIC MOTOR (5"/38)

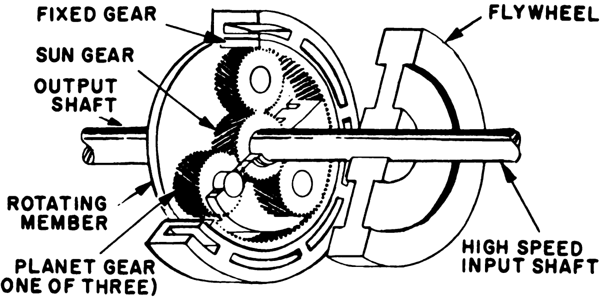
The prime mover, or electric drive motor, is of the squirrel-cage induction type. The motor drives the A-end of the hydraulic power transmission. Through reduction gears, it also drives the replenishing pump, control pressure pump, and the sump pump and oscillator.

A motor controller with its associated pushbutton stations starts and stops the electric motor and gives protection against overload and undervoltage. The controller is located in the upper handling room except on mounts having a ready service rotating ring which would bar access to the controller. In this case, the controller is mounted outside but near the handling room.

MAIN REDUCTION GEAR

The A-end pump is designed to operate at a speed of approximately 900 revolutions per minute. Since this speed is much lower than that of the electric motor, it is necessary to reduce the speed of rotation between the A-end and the electric motor. This speed reduction is performed by the planetary (main) reduction gears (fig. 5-3). The main reduction gear is mounted in a housing between the power motor and the A-end. A helical gear, called the sun gear, is mounted on the output shaft of the motor and three helical gears, known as planet gears, are grouped 120° apart on a rotating member.

The planet gears mesh with the sun gear and with a large fixed gear mounted in the reduction gear housing. As the sun gear rotates, driven by the electric power motor, the planet gears also rotate about the inside circumference of the fixed gear carrying with them the rotating member in which they are mounted. The A-end main shaft



2.211

Figure 5-3.—Planetary reduction gears.

(reduction gears output shaft) is spline-mounted in the rotating member which drives the output shaft at a fixed reduced ratio. A heavy flywheel, mounted in the drive shaft of the power motor, prevents any sudden change in speed of the power motor. Any flywheel is used to store energy. This energy in the flywheel helps to prevent changes in the speed of the electric motor due in part to the reaction through the power unit to the shock of gun fire (inertia) when the equipment is in any type of power control.

HYDRAULIC TRANSMISSION

The hydraulic transmission system includes the following components:

1. Electrically driven variable delivery hydraulic pump (A-end).
2. Main cylinder, containing the stroke control shaft. (This assembly is used in controlling the tilt of the A-end.)
3. B-end—a fixed displacement hydraulic motor.
4. Auxiliary pumps.

Q3. What drives the A-end of the hydraulic power transmission?

Q4. The A-end pump of the 5"/38 gun mount is designed to operate at what speed?

A-End

The train A-end is shown in figure 5-4, view A. It is an axial piston, variable delivery pump. The direction and volume of its output control the direction and speed of rotation of the B-end. It is driven at a constant speed by the electric motor through the main reduction gears. The A-end housing encases and supports the rotating assemblies of the pump.

The cylinder barrel is keyed to the main shaft. It contains nine cylinder bores. It is held against the valve plate by a spring. The pistons operating in the bores of the cylinder barrel are ground and lapped to a smooth working fit. A hole drilled through the front of each piston admits fluid for lubricating the connecting rod ends.

The connecting rods with ball-shaped ends connect the pistons to the socket ring. Each connecting rod is drilled throughout its length to admit fluid from the interior of the cylinder to the two end bearings.

The socket ring is a circular piece containing nine sockets in which the connecting rod ends are secured. A collar projects around the central opening on the rear surface of this ring. A radial bearing fits around this collar and, in turn, acts as an outer roller path for a thrust bearing. A circular plate on the tilting box serves as an inner roller path for the thrust bearing.

The socket ring is mounted on a trunnion block that rides inside the yoke of the main shaft. A pin, secured to the trunnion block, passes through the main shaft and rotates in bushings in the shaft. This arrangement acts as a universal joint for the socket ring. The trunnion block and, therefore, the attached socket ring, is free to rotate about the axis of the pin. This movement permits the tilting box to control the length of stroke of the pistons.

The tilting box encloses the socket ring and provides a means of varying the angle of the socket ring in relation to the main shaft, thus varying the length of the piston stroke from zero to maximum. The tilting box is a trunnion-mounted casting located inside the A-end housing.

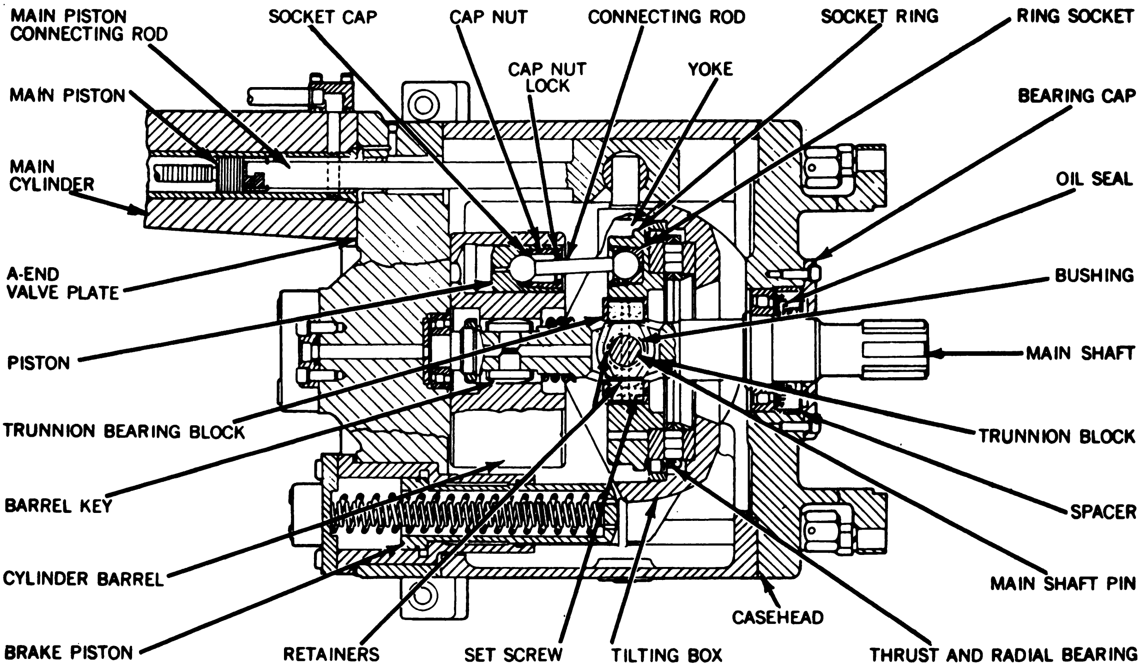
The tilting box can be rotated on its trunnions through a limited arc. When the tilting box is in a plane perpendicular to the main shaft, it is in the neutral position and there is no reciprocating motion of the pistons in their cylinders. Angular displacement from the perpendicular plane governs the output of the A-end. Movement of the tilting box is directly controlled by the stroke control shaft.

The valve plate is a stationary member and constitutes one end of the A-end case. The inner

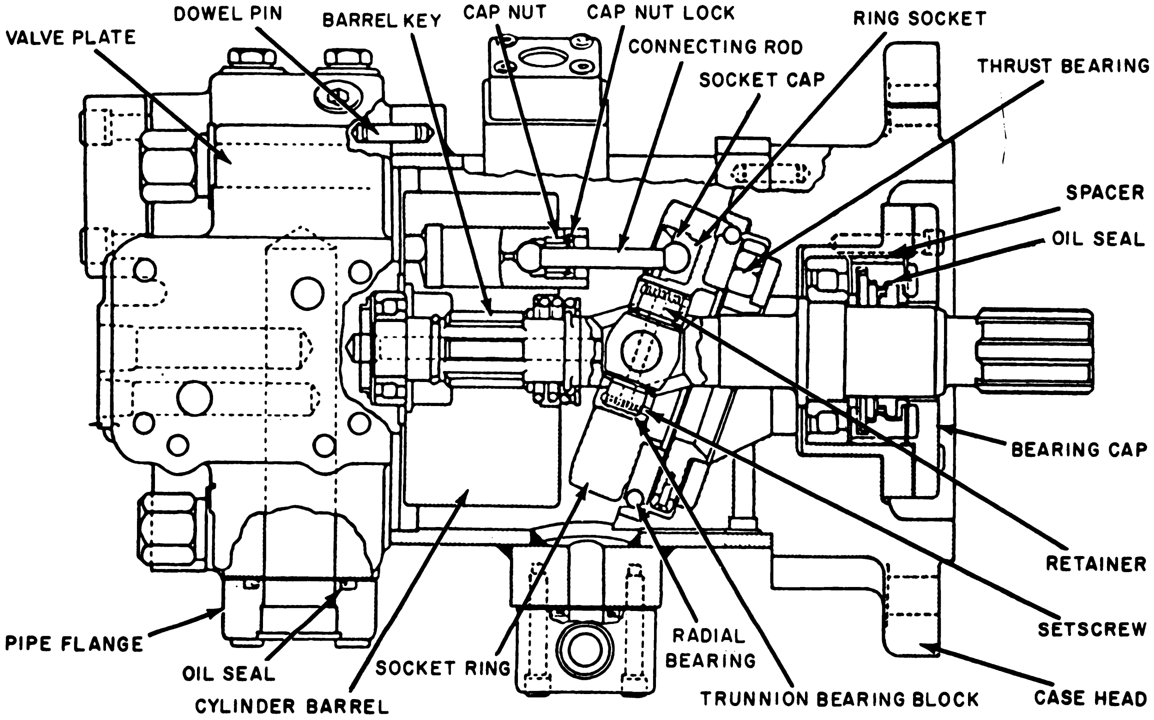
ANSWER TO QUESTIONS Q1 AND Q2.

A1. Variable delivery (displacement) pump.

A2. To retard or bring moving equipment to a smooth stop.



(A) A-END PUMP



(B) B-END MOTOR

53.70

Figure 5-4.—Hydraulic pump and motor.

face of the valve plate has a finished surface against which the cylinder barrel rotates. This surface is provided with two semiannular valve ports which receive and discharge fluid from the cylinders. The portions of the valve plate surface between the ports, called lands, are used to separate the driving oil from the returning oil.

The active system piping consists of two large copper pipes leading from the A-end valve plate ports to the B-end.

B-End

The B-end (figure 5-4, view B) is similar in construction to the A-end except that the tilt of the socket ring is fixed in the B-end. Fluid under pressure from the A-end will enter one of the grooves of the B-end valve plate and exert a force against the surface of the B-end pistons. The force against the face of the pistons will result in a thrust component causing a turning force to be imparted to the socket ring. The socket ring is mounted on an output shaft through a universal joint and rides on roller bearings on a roller track positioned at a 20° fixed angle in relation to the output shaft.

As the B-end pistons must each make a full stroke for every revolution of the output shaft, speed of the B-end and, hence, the speed at which the guns are elevated and trained is directly proportional to the angular displacement of the A-end tilting box from its neutral position.

The output shaft of the B-end motor is connected to the elevating and training pinions through a mechanical system of gearing and shafting. To compensate for misalignment of the B-end shaft and the final drive gearing, they are connected by flexible or self-aligning type couplings.

Auxiliary Pump Cluster

The auxiliary reduction gears are flange-mounted at the rear of the electric power motor. Three important pumps are driven by the motor through these gears.

REPLENISHING PUMP.—This pump is a spur gear pump driven at a constant speed by the electric motor through the auxiliary reduction gear. Its purpose is to replenish fluid for the active (transmission) system of the power drive.

The pump draws fluid from the reservoir and discharges it at a regulated pressure to the B-end valve plate.

The discharge of the pump is held at a constant pressure (normally between 25 and 50 psi) by the action of a compound relief and dump valve. Normally, because the capacity of the pump exceeds replenishing demands, the relief valve is continuously dumping some of the fluid to exhaust. This valve is adjustable.

SUMP PUMP AND OSCILLATOR.—This pump is also driven by the auxiliary reduction gears. Its purpose is two-fold. It pumps leakage fluid that collects in the sump of the indicator-regulator to the expansion tank.

Its other function is to transmit a pulsating effect to the fluid in the response pressure system. Oscillations in the hydraulic response system help eliminate static friction of valves to make the hydraulic control respond faster.

A cutaway drawing of this pump is shown in figure 5-5. The pumping piston has an extension of reduced diameter which operates through a bushing. The piston is spring loaded, ensuring constant contact with the rotating eccentric. The extension of the pumping piston through the bushing operates the second piston which provides the oscillation to the response pressure system. Lengthwise movement of the bushing varies the amount of oscillation produced. An eccentric pin (controlled by an external adjustment) positions the bushing to obtain a satisfactory standstill condition with a minimum of oscillation.

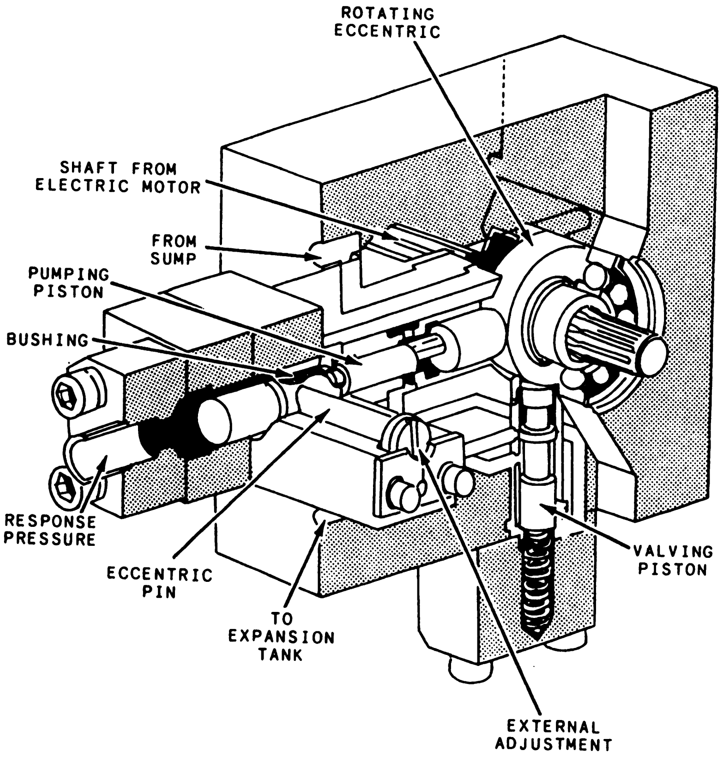
The valving piston and the pumping piston act in conjunction to port fluid from the sump of the indicator-regulator to the pumping piston where it is pumped into the expansion tank.

CONTROL PRESSURE PUMP.—The remaining pump driven by the auxiliary reduction gears is the control pressure pump (fig. 5-6). Its

ANSWER TO QUESTIONS Q3 AND Q4.

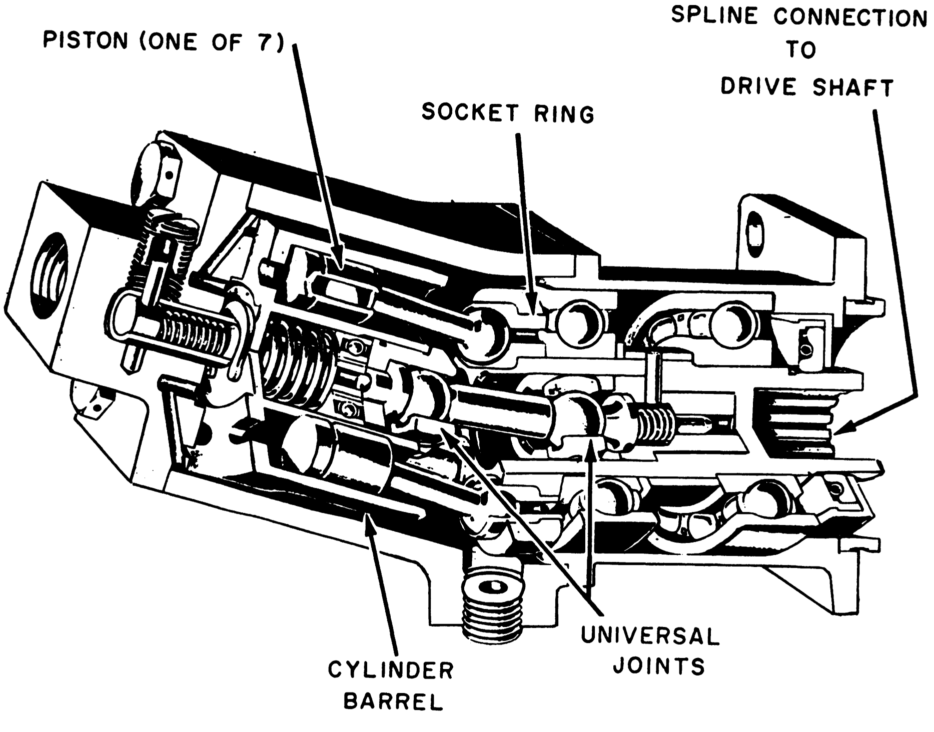
A3. Electric drive motor.

A4. About 900 rpms.



53.71

Figure 5-5.—Sump pump and oscillator.



53.72

Figure 5-6.—Control pressure pump.

function is to supply fluid for the hydraulic control system, brake pistons, lock piston (at the antioverhaul valve block), and the hand-control clutch operating piston.

The control pressure pump is an axial piston pump. As described earlier in the chapter, it is similar to the A-end pump except that the angle of tilt is permanently fixed. Consequently, the pump produces a constant volume output.

To limit the pressure of the pump output to operating pressures, an adjustable relief valve, identical with that of the replenishing pump relief valve, is used. Control pressure can be measured by inserting a gage in the plug hole located in the relief valve block. Changing the pressure is accomplished at the relief valve by a simple screw type of adjustment.

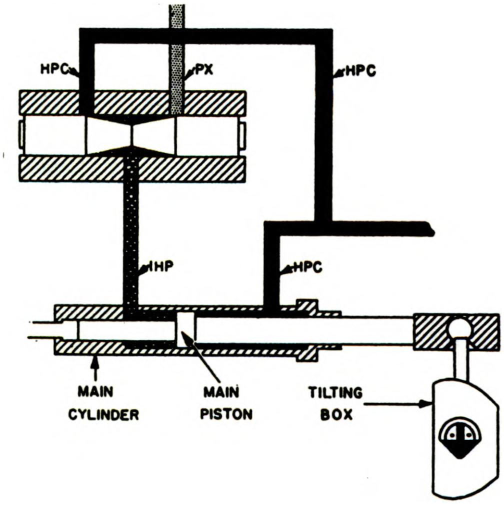
Q5. What controls the direction and speed of the B-end?

Q6. What three pumps are driven by the motor through the reduction gears?

CONTROL

Control, as it pertains to the indicator-regulator and the handwheel bracket, will be studied in detail in chapter 6. For the purposes of this chapter, we can say that it constitutes the relationship between the stroke control shaft and the tilting box. The stroke control shaft is physically located in the main cylinder (fig. 5-7). It is the link between the hydraulic follow-up system and the power drive itself.

In hand control, the titling box is mechanically positioned by gearing from the handwheels through the A-end control unit. In local and automatic control, the tilting box is positioned by the stroke control shaft. This shaft is connected at one end to the tilting box. On the other end the main piston is operating in the main cylinder. Intermediate high pressure (IHP) is transmitted to one side of the piston. The other side of the main piston is connected to high pressure, which is held constant (HPC) at 1000 psi. Since the area upon which HPC acts is exactly one-half of the area upon which IHP acts, the main piston will be held fixed in one position when IHP is one-half of HPC. Whenever IHP varies from its normal value of one-half HPC, because of action of various control valves, the main piston will move, and thus cause movement of the tilting box.

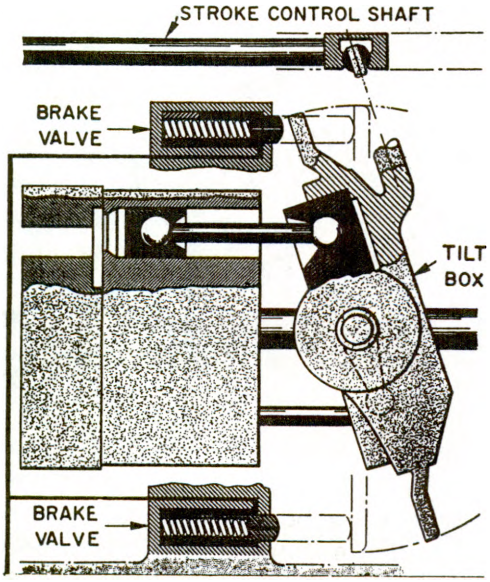


53.73

Figure 5-7.—Main cylinder assembly.

BRAKE VALVES

An assembly consisting of two brake valves (pistons) acts to force the titling box to its zero position whenever control pressure is released (fig. 5-8). These spring-loaded pistons are normally



53.74

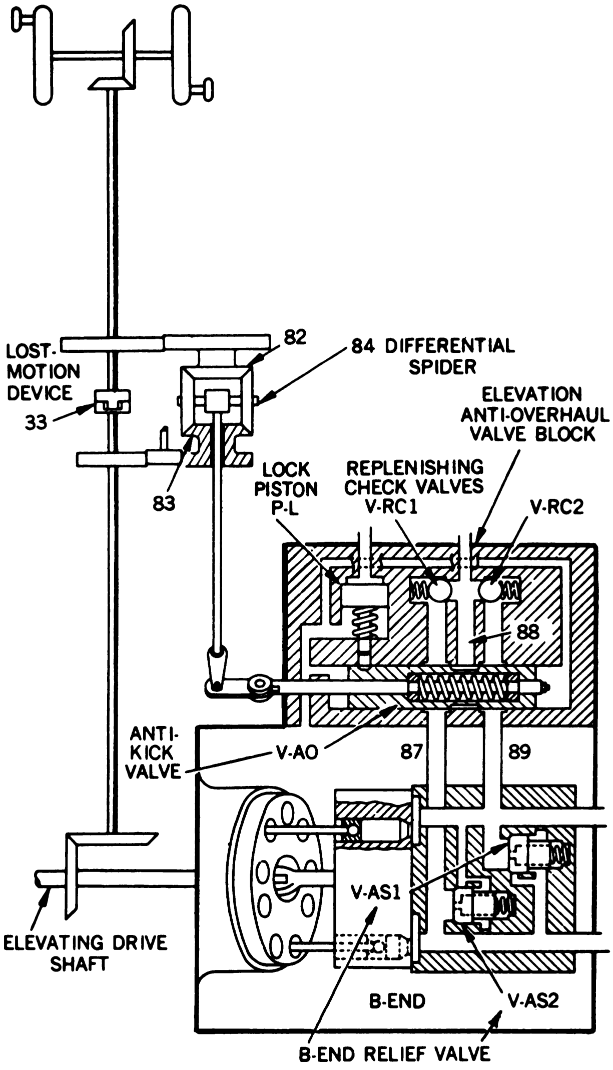
Figure 5-8.—Brake valves.

held back against the spring pressure to allow the tilting box free movement in hand, local, or automatic control. This is done by fluid pumped at high pressure from the control pressure pump. When fluid pressure drops, the pistons are moved by their springs to center the tilting box. The brake valves are adjustable in both the train and elevation drives, but by different means. In the train power drive, shims are provided on the valve plate end of the brake pistons. These shims permit adjustment of the pistons to bring the tilting box to an absolute zero position when they are released.

This function is accomplished in the elevation power drive by a creep eccentric adjustment. This is an eccentric camshaft fitted into a opening in the bottom of the brake piston and stroke shaft assembly housing. The creep eccentric acts primarily as a stop for the brake pistons. By adjusting the creep eccentric, you can cause the brake pistons to bring the tilting box to the exact neutral position, and thus prevent the mount from creeping while the brake pistons are released.

ANTIOVERHAUL MECHANISM

When the mount is in manual control, the A-end is at neutral so that there can be no fluid flow between the two ends of the hydraulic transmission system. The manual drive, however, is connected to the output shaft of the B-end. When the mount moves, the B-end rotates and acts as a pump. The pressure thus built up would cause a hydraulic block, preventing movement of the mount if not relieved. A diagram of the antioverhaul mechanism is shown in figure 5-9.



53.75

Figure 5-9.—Antioverhaul mechanism.

ANTIKICK ACTION

This pressure is relieved by action of the antikick valve, which transfers this fluid flow from one side of the B-end to the other. It also prevents the flow of fluid in the opposite direction when the direction of gun movement is reversed by gun fire. This prevents gun fire shock from being transferred to the handwheel.

The valve block is secured to the B-end unit. It houses the replenishing check valves, the lock piston, and the antikick valve. When the mount is in any type of control other than manual, the antikick valve is locked in its neutral position by the lock piston.

The antikick valve is connected to the handwheel drive through the lost motion device and a differential. Initial movement of the handwheel causes the upper section of the lost motion device and the primary gear of the differential to rotate before the lower section of the lost motion device. During this time the spider of the differential rotates with the primary gear and positions the antikick valve. After the lost motion has been taken up, the lower section of the lost motion device begins to turn, moving the mount. The spider stops moving and remains stationary as long as the mount is being driven in the same direction. If handwheel movement is reversed, the position of the antikick valve is reversed.

Now, suppose the mount is placed in manual control and the handwheel is rotated. During the first small amount of handwheel rotation, the antikick valve is shifted, opening either line 87 or 89 to chamber 88 (fig. 5-9). Fluid pumped by the B-end will flow through one of the lines, through the antikick valve, through chamber 88, and lift the check valve of the other line. It enters and flows through the other line and returns to the B-end.

Should gunfire cause a kickback, the B-end immediately acts to reverse the direction of fluid flow. The check valves, however, will allow a flow of fluid into lines 87 and 89, and not out. Therefore, reversal of the B-end is hydraulically blocked, and the B-end will take the shock of kickback. If kickback reaction is extremely violent, the B-end relief valve may be forced momentarily to open one side of the active system to the other and thereby prevent damage to the equipment.

Should the mount tend to overhaul the handwheel movement as a result of gunfire, the lower section of the lost motion device momentarily rotates faster than the upper section. This causes the secondary gear to rotate faster than the primary gear. The spider will then rotate in a direction opposite to its original one, moving the antikick valve in the opposite direction. This creates a hydraulic block, as for kickback, and prevents further overhaul rotation of the B-end. As a result, the upper part of the lost motion device cannot be driven by gun overhaul, and the reaction cannot reach the handwheels.

The antikick valve is adjustable in both train and elevation power drives, but by different methods. In either drive the check for error in adjustment is the same. With the selector controls set at MANUAL and LOW, rotate the handwheels slowly in both directions. If there is an appreciable error in adjustment, the resistance of the handwheels will differ greatly for the two directions of rotation, and the output will be rough in one direction. In this case, adjust the antikick valve linkages in accordance with the instructions in OP 805.

Q7. In automatic control, what component positions the tilting box?

THE 5″/54 MK 42 MODS 9 AND 10 GUN MOUNT POWER DRIVES

The train and elevation power drives for the 5″/54 Mk 42 Mods 9 and 10 gun mounts are basically alike; therefore, only the train drive will be discussed here.

GENERAL DESCRIPTION

The train power drives on the 5″/54 Mods 9 and 10 gun mounts operate at the same time or independently with the elevation power drive to position the gun in response to electrical gun order signals. The train power drive consists of an electric motor, speed reducer, auxiliary gear pump, auxiliary relief valve block, servo accumulator, header tank, sump, sump pump and motor, hydraulic transmission (CAB unit), pinion and worm drive, power-off brake, air motor, and receiver-regulator. Figure 5-10 shows you the layout of the principal components of the train power drive.

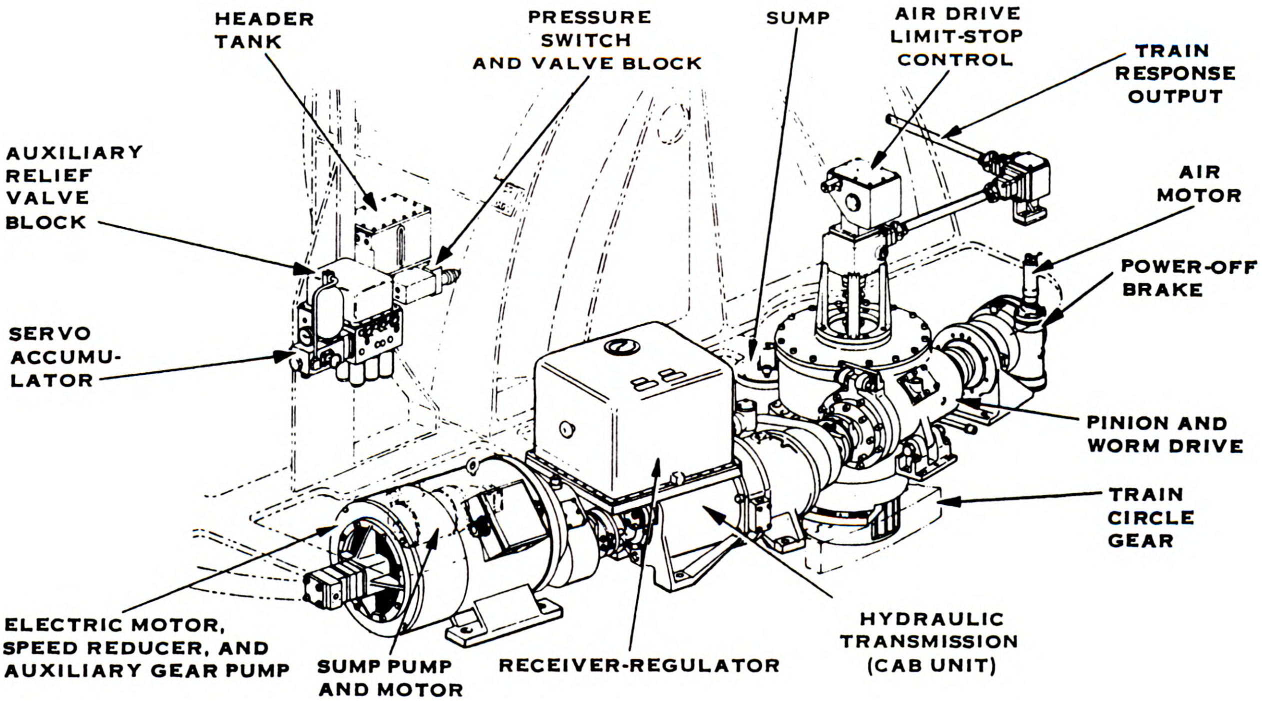
ELECTRIC MOTOR AND SPEED REDUCER

The train electric motor and speed reducer assembly provide a constant speed input to the hydraulic transmission. The motor is a 440-volt motor rated at 60 horsepower. The drive shaft out the front of the motor is attached to the drive gear of the speed reducer. To the rear of motor, the drive shaft drives the auxiliary gear pump, which furnishes both control and replenishing pressure to the hydraulic system.

ANSWER TO QUESTIONS Q5 AND Q6.

A5. A-end output.

A6. Replenishing pump, sump pump, and control pressure pump.

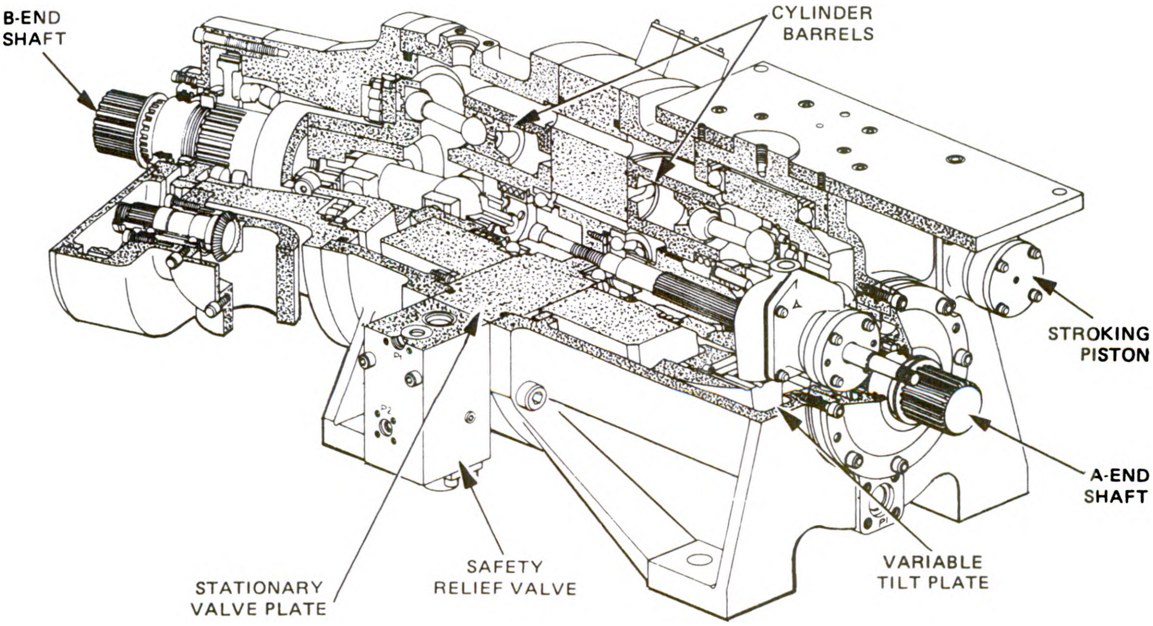

HEADER TANK
PRESSURE SWITCH AND VALVE BLOCK
SUMP
AIR DRIVE LIMIT-STOP CONTROL
TRAIN RESPONSE OUTPUT
AUXILIARY RELIEF VALVE BLOCK
AIR MOTOR
POWER-OFF BRAKE
SERVO ACCUMU-LATOR
PINION AND WORM DRIVE
TRAIN CIRCLE GEAR
HYDRAULIC TRANSMISSION (CAB UNIT)
ELECTRIC MOTOR, SPEED REDUCER, AND AUXILIARY GEAR PUMP
SUMP PUMP AND MOTOR
RECEIVER-REGULATOR

53.342

Figure 5-10.—5″/54 Mk 42 Mods 9 and 10 train power drive.

HYDRAULIC TRANSMISSION (CAB UNIT)

The hydraulic transmission converts a constant speed, mechanic input into a variable speed, bidirectional output. The CAB unit consists of an axial-piston pump (fig. 5-11) with a variable tilt plate (A-end), a hydraulic motor (B-end), a stationary valve plate that connects the A-end to the B-end, a safety relief value to relieve the



53.343

Figure 5-11.—Typical CAB unit.

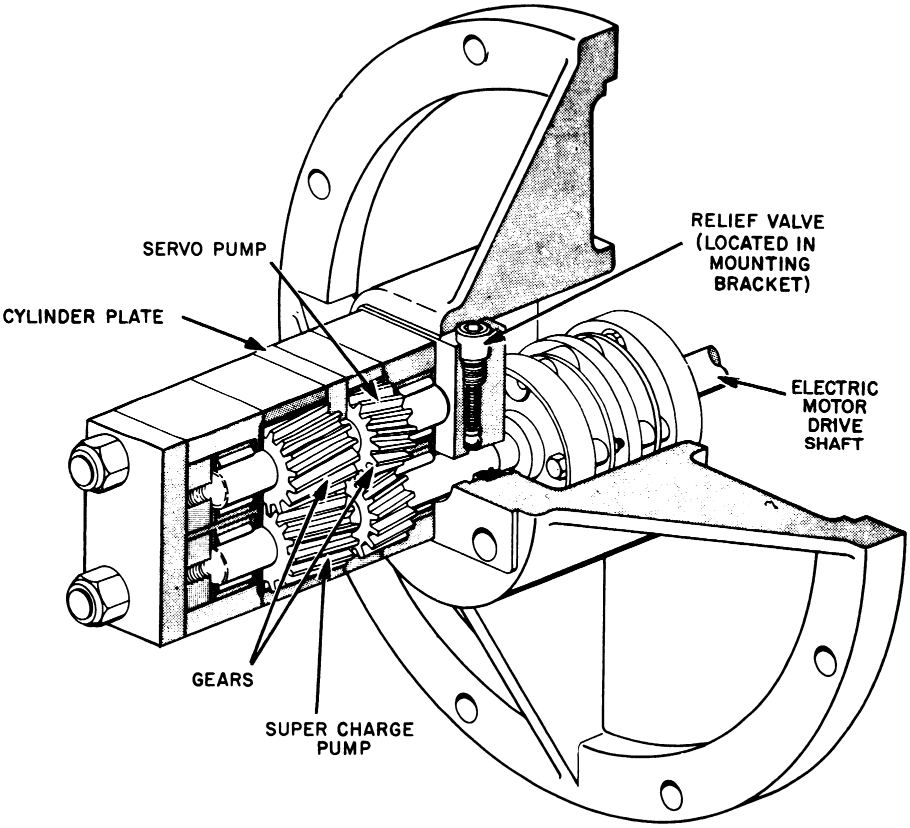
A-end of excessive pressure, and supercharge check to admit replenishing fluid lost through slippage.

AUXILIARY GEAR PUMP

The auxiliary pump mounted on the rear of the electric motor (fig. 5-12) is a two-section gear pump driven through a flexible coupling by the electric motor. The front section is the servo pump. The rear section is the supercharge pump. Each section draws hydraulic fluid from a reservoir, through a common intake line, and discharges it through separate lines. The servo pump supplies hydraulic fluid to the auxiliary relief value block. In the valve block it is regulated to two pressures—a servo pressure and a control pressure. The supercharge pump supplies hydraulic fluid to the auxiliary relief valve block where it is regulated. After regulation, the fluid is applied to the circulating system of the hydraulic transmission to replenish fluid lost through leakage.

AUXILIARY RELIEF VALVE BLOCK

The auxiliary relief valve block (fig. 5-13) filters and regulates servo and supercharge fluid from the auxiliary gear pump. In addition, the valve block controls the porting of filtered and

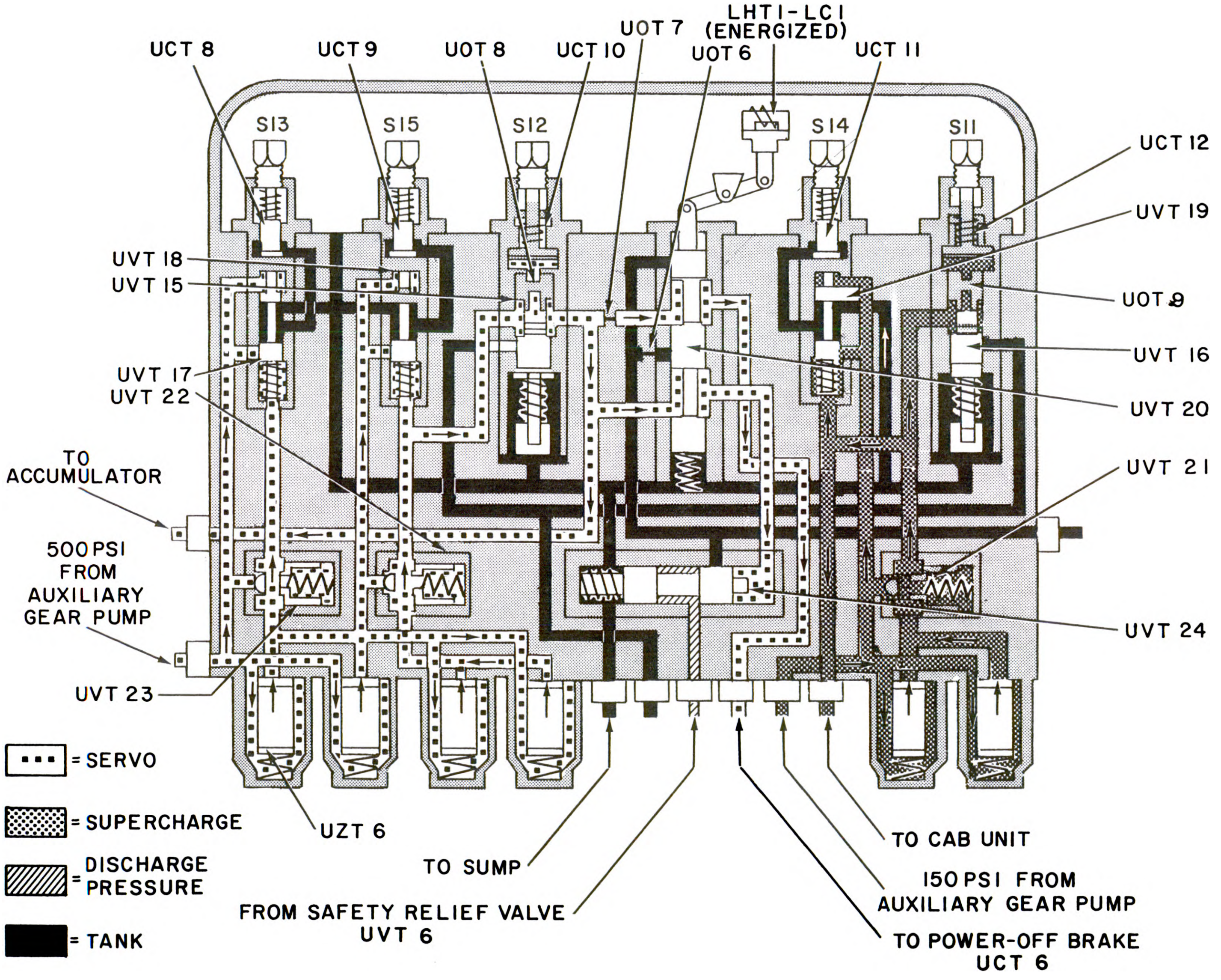


53.344

Figure 5-12.—Train auxiliary gear pump.

ANSWER TO QUESTION Q7.

A7. The stroke control shaft.



53.345

Figure 5-13.—Train auxiliary relief valve block.

regulated servo fluid to the power-off brake. Regulated and filtered servo fluid is discharged to the servo accumulator to provide operating pressure for the receiver-regulator, and filtered and regulated supercharge fluid is ported to the CAB unit to cool and replenish it. The components inside the auxiliary relief valve blocks are functionally subdivided into three component groups—filtration, pressure regulation, and power-off brake control.

Filter Components

Six filters (two for supercharge fluid and four for servo fluid) are mounted in the auxiliary valve block. Each filter element has a cartridge enclosed in an individual bowl, threaded for easy removal. When one or more of the filter elements become clogged, a pressure drop is developed across the affected element(s) and at the spring end of the associated pilot valve(s). The pressure drop causes the associated filter bypass valve and pilot valve to shift and open lines to the underside of pressure switch piston UCT8, UCT9, or UCT11. The affected piston, in turn, actuates filter clogged switch S13, S15, or S14.

When any one of these filter clogged switches is actuated, it completes a circuit to the ALL MOTORS-CHECK FILTERS lamp and to the TRAIN MOTOR-STOP pushbutton lamp on the EP2 panel. As clogging increases, the pressure drop increases across both the filter element(s) and the associated filter bypass valve(s). When the increased pressure drop unseats the bypass valve, it ports hydraulic fluid around the clogged element(s) and unfiltered fluid circulates in the system.

Let's continue our inspection of the auxiliary relief valve diagramed in figure 5-13. If filter element UZT6, for example, begins to clog, the pressure at the inlet to the filter begins to rise. This pressure difference is felt between unfiltered fluid on top and filtered fluid on the bottom of UVT17 and between the left and right sides of UVT23. As clogging increases, increasing pressure on the top of UVT17 allows the valve to shift down against spring pressure. As UVT17 shifts down, unfiltered servo fluid is ported through the middle chamber of the valve to the bottom of UCT8. Piston UCT8 is shifted up to actuate train servo filter clogged switch S13. If the filter is not replaced, the rising pressure difference between the left and the right sides of UVT23 shifts the filter bypass valve to the right and unfiltered fluid circulates in the system. The other filter units in the valve block operate in the same manner.

Pressure Regulation Components

From the filter elements and their associated filter bypass valves, servo and supercharge fluid is ported to servo relief valve UVT15 and supercharge relief valve UVT16, respectively. These valves relieve excess servo and supercharge pressures in the hydraulic system by bleeding fluid to tank if system pressure rises too high. If system pressure falls too low, switches above the relief valves open the train motor run circuit and stop the motor.

After passing through the filter units, servo fluid is ported to the middle chamber of UVT15 (fig. 5-13). Fluid flows up inside the middle chamber through UOT8 to the top of UVT15. If fluid pressure in the system rises above the preset tension of the valve spring, fluid pressure above UVT15 shifts UVT15 down, opening a port in the middle chamber to tank. This action produces a pressure drop in both the middle chamber and the chamber above the plunger. When pressure above UVT15 falls back below the preset tension of the valve spring, the spring shifts the plunger back up to close the port to tank.

Hydraulic pressure on top of plunger UVT15 also acts on pressure switch piston UCT10. As long as servo pressure is maintained at the proper level (approximately 400 to 500 psi), fluid pressure holds UCT10 up against spring pressure, and train servo pressure normal switch S12 remains closed. If, however, pressure falls below the level needed to complete the hydraulic operations controlled by the auxiliary relief valve block, spring pressure shifts UCT10 down and deactuates S12. When S12 is deactuated, it opens the circuit to the train motor contactor and stops the train motor. Servo fluid is ported from the middle chamber of UVT15 to the servo accumulator, through UOT7 and the upper chamber of UVT20 to the power-off brake, and through the bottom chamber of UVT20 to the right end of UVT24.

The operation of supercharge pressure-regulating valve UVT16 is similar to the operation of UVT15. The spring tension of UVT16 is preset, however, to regulate supercharge fluid at approximately 150 psi. After filtration and pressure regulation, supercharge fluid is ported to UVT10 and UVT11 in the train CAB unit.

Power-Off Brake Control Components

Power-off brake release valve UVT20 (fig. 5-13) is a solenoid-controlled valve. When LHT1-LC1 energizes, UVT20 is shifted down.

This ports servo fluid through the upper chamber of UVT20 to brake-release piston UCT6 and through the bottom chamber of UVT20 to UVT24.

Valve UVT24 delays the operation of safety relief valve UVT6 in the train CAB unit when LHT1-LC1 deenergizes. If power is lost, this delay maintains pressure in the CAB unit by keeping UVT6 seated. As long as UVT6 remains seated, the train B-end continues to operate, keeping the CAB unit under control until the power-off brake holds the mount. Orifice UOT6 delays the movement of UVT24 to ensure that the power-off brake is in control of the B-end before UVT24 shifts to the right and opens the discharge pressure line from UVT6. Orifice UOT7 delays the release of the power-off brake until UVT24 shifts to the left and closes the discharge pressure line from UVT6.

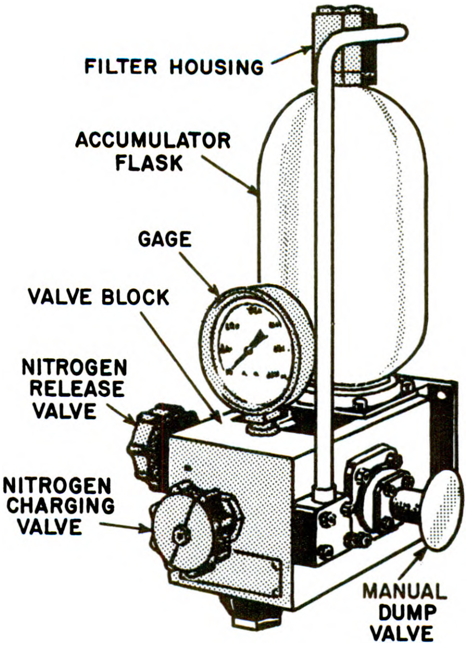
The train power-off brake will be discussed more thoroughly in the following chapter.

Q8. *The electric motor of the 5"/54 Mk 42 Mods 9 and 10 is rated at what horsepower?*

Q9. *What component regulates and filters servo and supercharge fluid?*

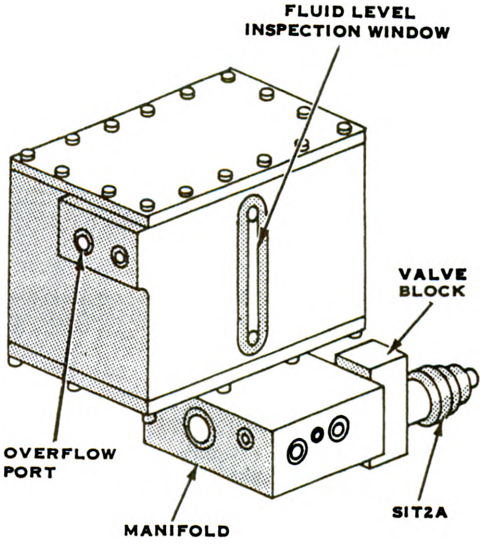
TRAIN SERVO ACCUMULATOR

The train servo accumulator (fig. 5-14) is mounted on the train auxiliary relief valve block. It provides a small reserve of hydraulic fluid at servo pressure to meet the instantaneous peak demands of the train system. The accumulator also dampens hydraulic fluid surges in the train system. The servo accumulator assembly consists of a valve block, an accumulator flask, a manual dump valve, a nitrogen charging valve, a nitrogen release valve, a gage, and a filter housing.



53.346

Figure 5-14.—Train servo accumulator.



53.347

Figure 5-15.—Train header tank.

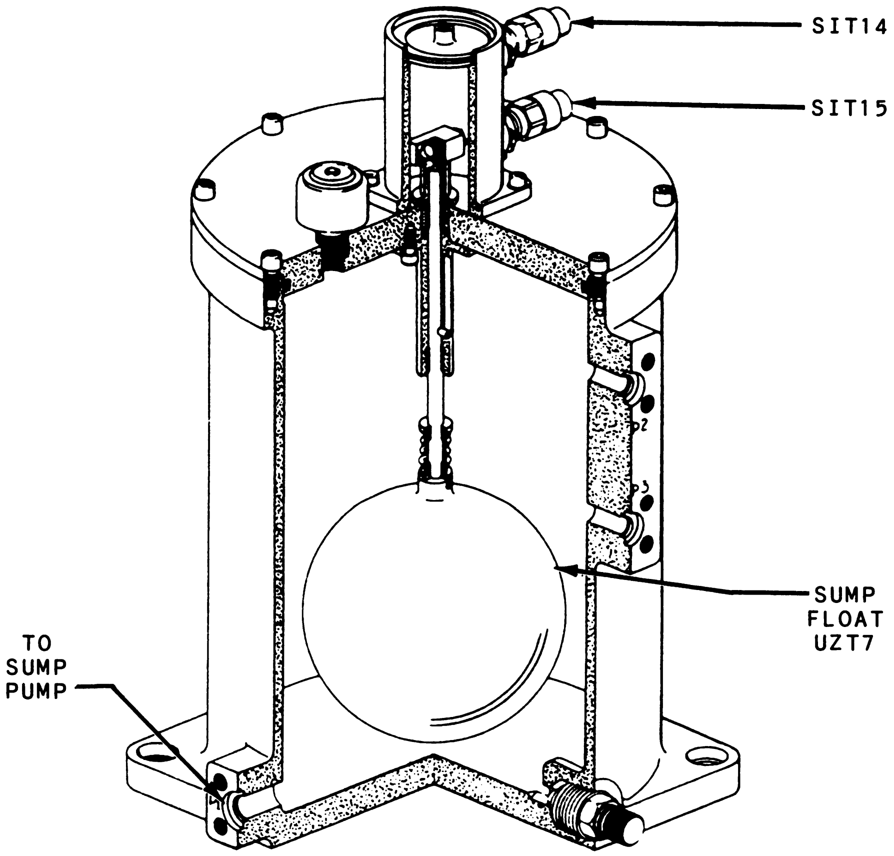
HEADER TANK

The train header tank (fig. 5-15) is mounted on the right cradle guide arc support bracket. It maintains a gravity head of hydraulic fluid on the train system tank lines. Excess fluid accumulated in the tank drains through an overflow port back to the main supply tank. The header tank has a fluid level inspection window on the outboard side and a fill and drain valve on the bottom. The train pressure cutout switch (SIT2A) and its valve block are mounted on the header tank manifold. The switch functions to prevent damage to the train

CAB unit due to prolonged excessive pressure in the A-end.

SUMP

The train receiver-regulator is almost on a level with the main supply tank. Because of this, a sump is needed to collect the leakage of fluid from the receiver-regulator and the train auxiliary relief valve block and return it to the train header tank. The sump (fig. 5-16) is mounted in a base ring compartment inboard of the train CAB unit and collects fluid drainage within the train system. There are three hydraulic lines that connect to the sump. Two of these lines serve as drains for leakage from the train auxiliary relief valve block and the train receiver-regulator. The third line is the suction line to the sump pump. On top of the sump housing is a switch housing which contains the train sump float-up switch (SIT14) and the train sump float-down switch (SIT15). A float that moves up or down with the fluid level in the sump activates the switches that control the sump motor operation. A breather is mounted on top of the sump housing and a drain plug is located at the bottom of the sump housing. (The elevation power drive does not require a sump because the



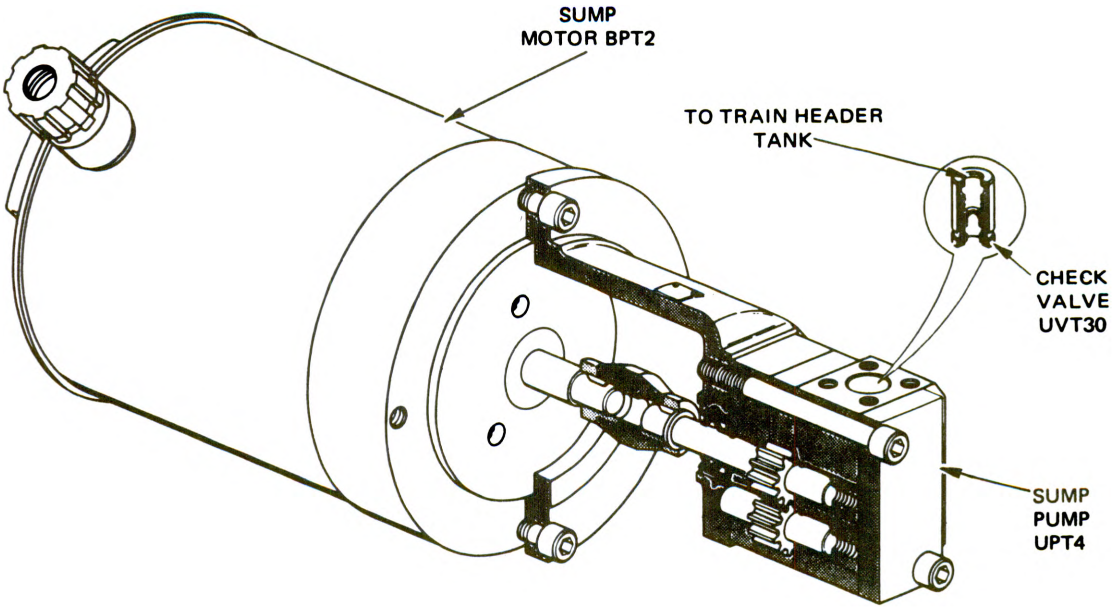
53.348

Figure 5-16.—Sump.

ANSWER TO QUESTIONS Q8 AND Q9.

A8. 60.

A9. Auxiliary relief valve block.



53.349

Figure 5-17.—Sump pump and motor.

receiver-regulator is mounted above the main supply tank.)

SUMP PUMP AND MOTOR

The sump motor (fig. 5-17) is mounted in a base ring compartment inboard of the train motor. The sump pump is mounted on, and driven by, the sump motor through a flexible coupling. The pump withdraws hydraulic fluid from the sump and discharges it to the train header tank. A check valve, located in the pump discharge line, prevents hydraulic fluid from draining back into the sump from the header tank.

Q10. What method is used to check the fluid level on the header tanks?

Q11. What component prevents fluid from drawing back into the pump from the header tank?

THE 5″/54 MK 45 MOD 0 GUN MOUNT POWER DRIVE

The power drives for the 5″/54 Mk 45 Mod 0 gun mount consists of the train and elevation power drives. The train power drive responds to one set of order signals to rotate the carriage, while the elevation power drive responds to another set of order signals. Activation of the power drives occurs as follows:

1. The elevation and train motors are started. The elevation motor is started first because it furnishes servo and supercharge fluid to both the elevation and train power drives.

2. The power-off brakes release when a mode of operation is selected.

3. After being assigned to a fire control system by weapons control, the mount trains and elevates in response to a remote signal.

GENERAL DESCRIPTION

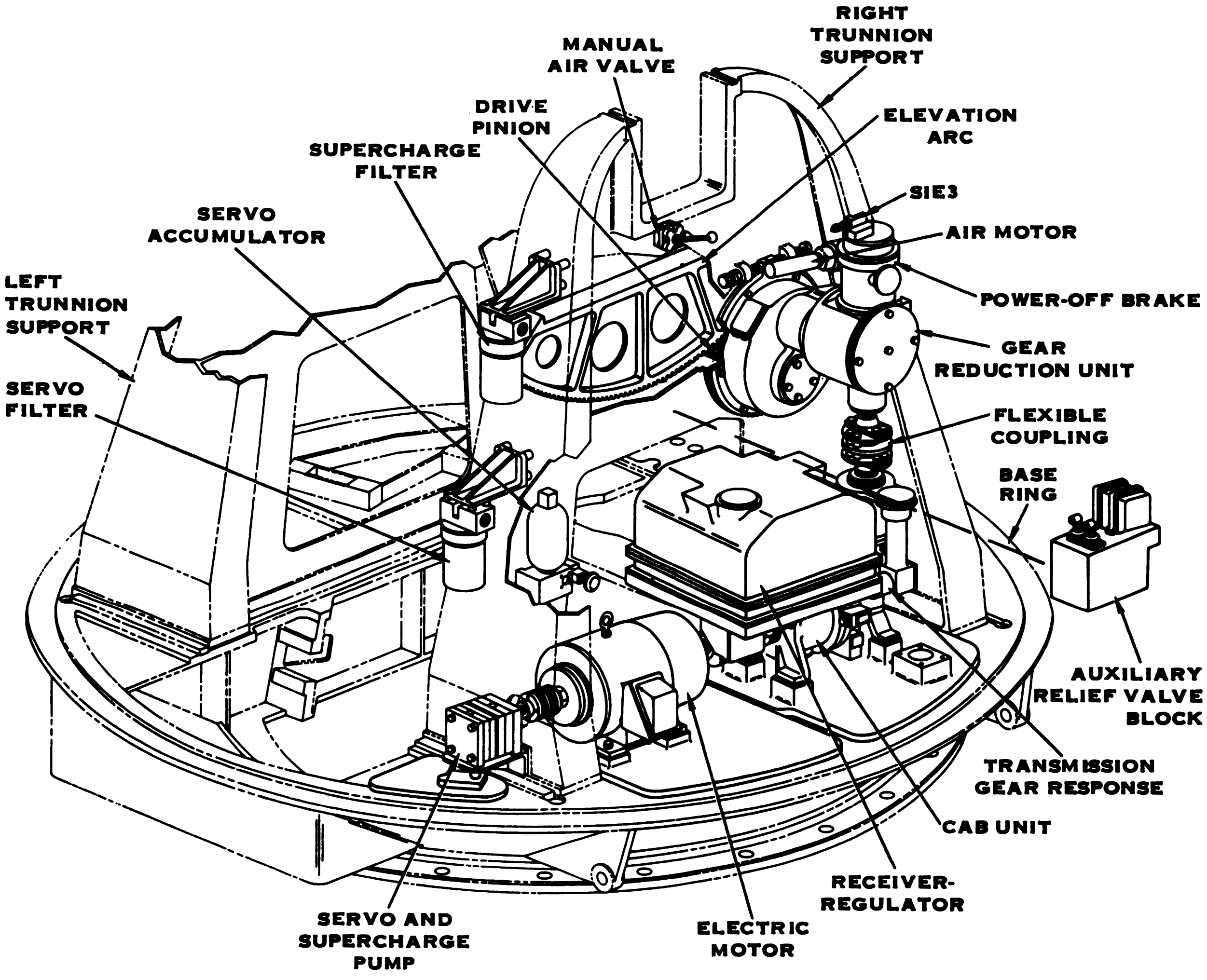
The power drives for 5″/54 Mk 45 gun mount are physically smaller than those used on the 5″/54 Mk 42 gun mounts because the Mk 45 gun mount is lighter in weight. Other than size, the main difference involves the use of only one gear pump and one auxiliary relief valve block to provide the fluid pressure for both the train and elevation power drive servo and supercharge requirements. Because the train and elevation power drives on this mount operate in a similar manner, only the elevation power drive is presented. Figure 5-18 shows the arrangement of the principal elevation power drive components.

ELECTRIC MOTOR (5"/54)

Except for being smaller, the 15-horsepower electric motor is constructed like, and functions the same as, the motors for the other 5"/54 power drives.

HYDRAULIC TRANSMISSION (CAB UNIT)

This CAB unit (fig. 5-19), like the other 5"/54 power drive CAB units, consists mainly of an A-end, a valve plate, and a B-end. The



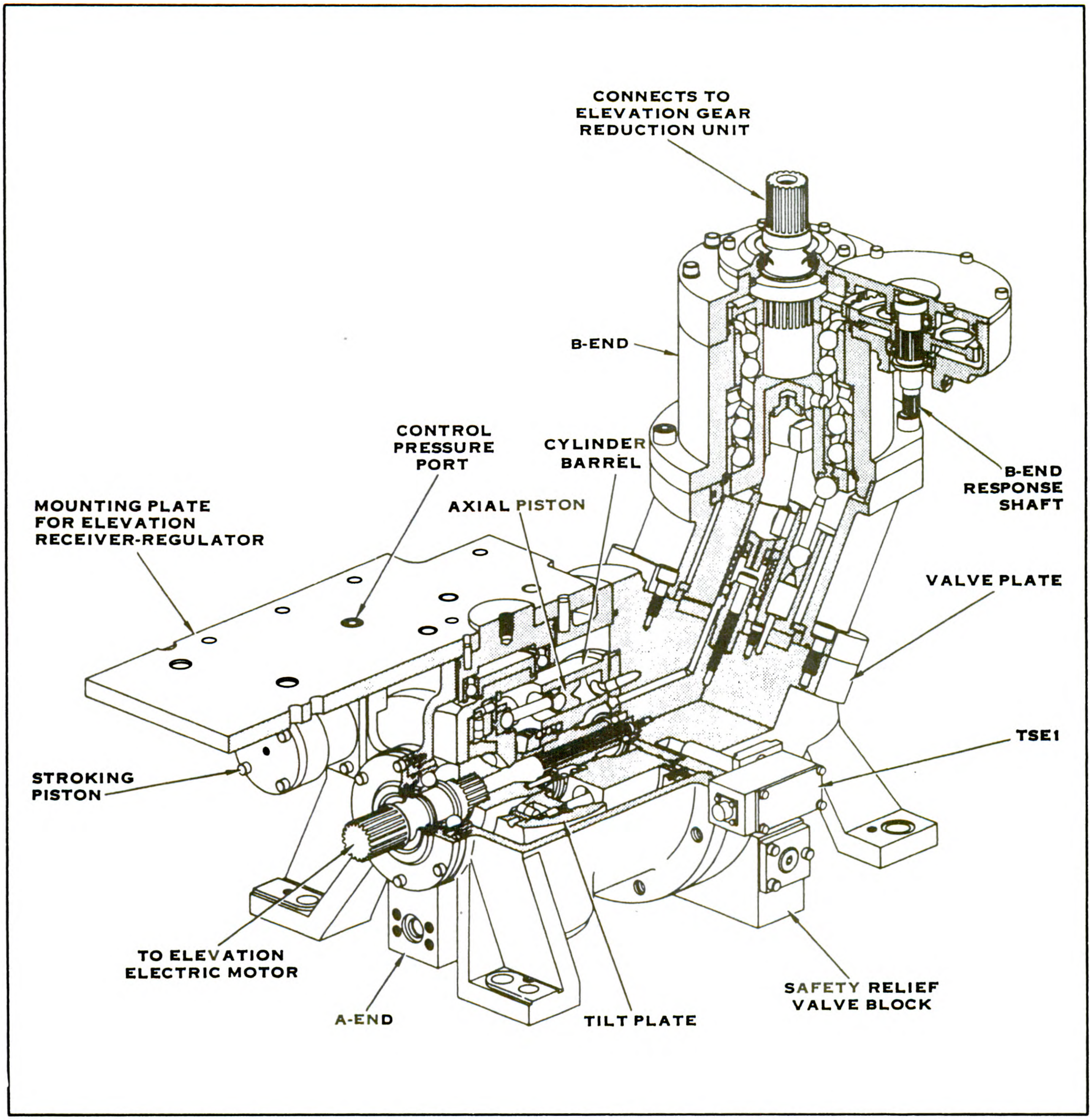
53.350

Figure 5-18.—Elevation system power drive.

ANSWER TO QUESTIONS Q10 AND Q11.

A10. Inspection window.

A11. Check valve.


CONNECTS TO ELEVATION GEAR REDUCTION UNIT
B-END
CONTROL PRESSURE PORT
CYLINDER BARREL
MOUNTING PLATE FOR ELEVATION RECEIVER-REGULATOR
AXIAL PISTON
B-END RESPONSE SHAFT
VALVE PLATE
TSE1
STROKING PISTON
TO ELEVATION ELECTRIC MOTOR
A-END
TILT PLATE
SAFETY RELIEF VALVE BLOCK

53.351

Figure 5-19.—Elevation CAB unit (cutaway view).

construction features of these units were covered in detail earlier in this chapter. Here, a review of how they operate is presented.

A-End

The A-end is coupled to and driven by the elevation electric motor. Controlled hydraulic fluid from the receiver-regulator, acting on stroking pistons in the A-end, controls the volume and direction of fluid which the A-end pumps to the B-end. The A-end output, therefore, controls the speed and direction of rotation of the B-end output shaft.

The cylinder barrel in the A-end (fig. 5-20) contains nine pistons located axially around the drive shaft. The pistons reciprocate (move back and forth) within the cylinder bores, drawing fluid in during 180° rotation of the A-end and discharging fluid during the other 180° rotation. The volume of fluid pumped depends on the length of piston travel in the cylinder bore which is determined by the angle of the variable tilt plate. Two stroking pistons, one on each side of the tilt plate, control the tilt plate angle.

Valve Plate

The stationary valve plate between the A-end and B-end has two crescent-shaped ports. The valve plate keeps the fluid being drawn into the A-end separate from the fluid being discharged under pressure to the B-end.

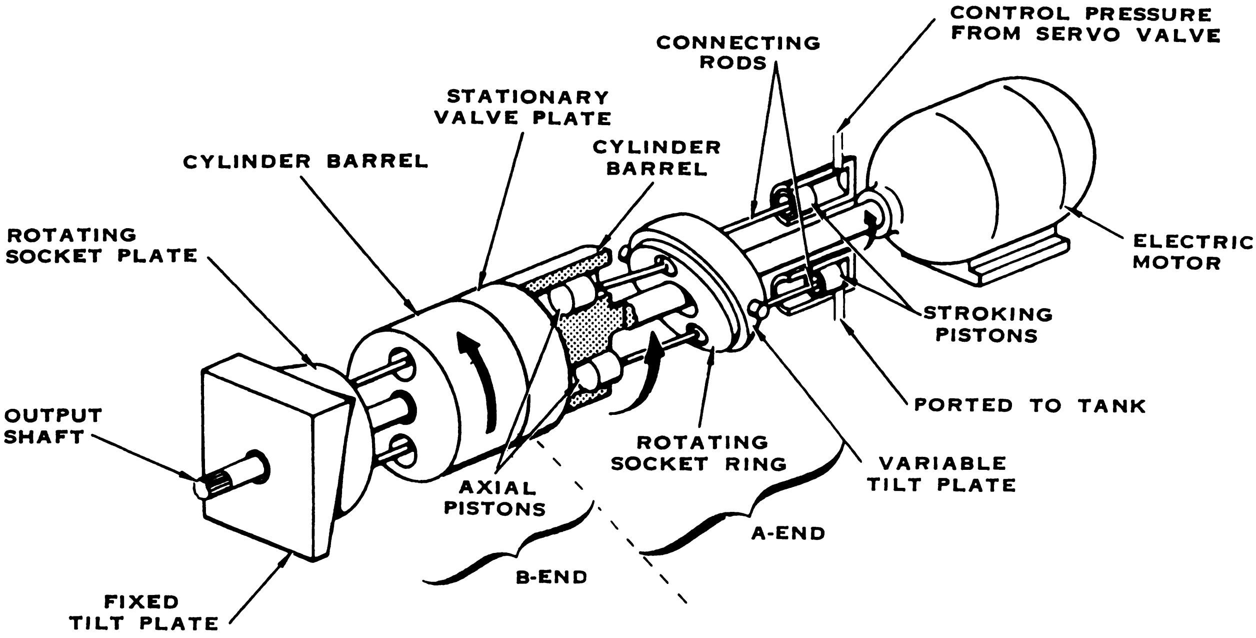
B-End

The B-end, with its fixed position tilt plate, operates in a reverse manner from the A-end, converting fluid flow into rotary motion. When fluid output from the A-end piston is applied to the B-end piston, the resultant thrust of the ball-end connecting rod against the inclined socket ring causes the socket ring to rotate. A universal joint connects the socket ring to the B-end output shaft so that both the output shaft and the cylinder barrel rotate with the socket ring (fig. 5-20). The cylinder barrel rotates against the two crescent-shaped ports in the valve plate. One port supplies A-end fluid to the axial pistons for a thrust stroke, the other port receives displaced fluid from the pistons on the retract stroke. During continuous rotation of the B-end, hydraulic fluid from the A-end is applied to the piston for the thrust stroke. As the cylinder bore moves past the land separating the two ports, fluid empties into the discharge port as the piston moves in the retract stroke. The discharge port for the B-end, which is replenished with supercharge fluid, connects to the intake port for the A-end. This action keeps hydraulic fluid in the CAB unit circulating within a closed loop, with only supercharge fluid replenishing fluid lost through slippage.

Q12. The electric motor of the 5"/54 Mk 45 Mod 0 is rated at what horsepower?

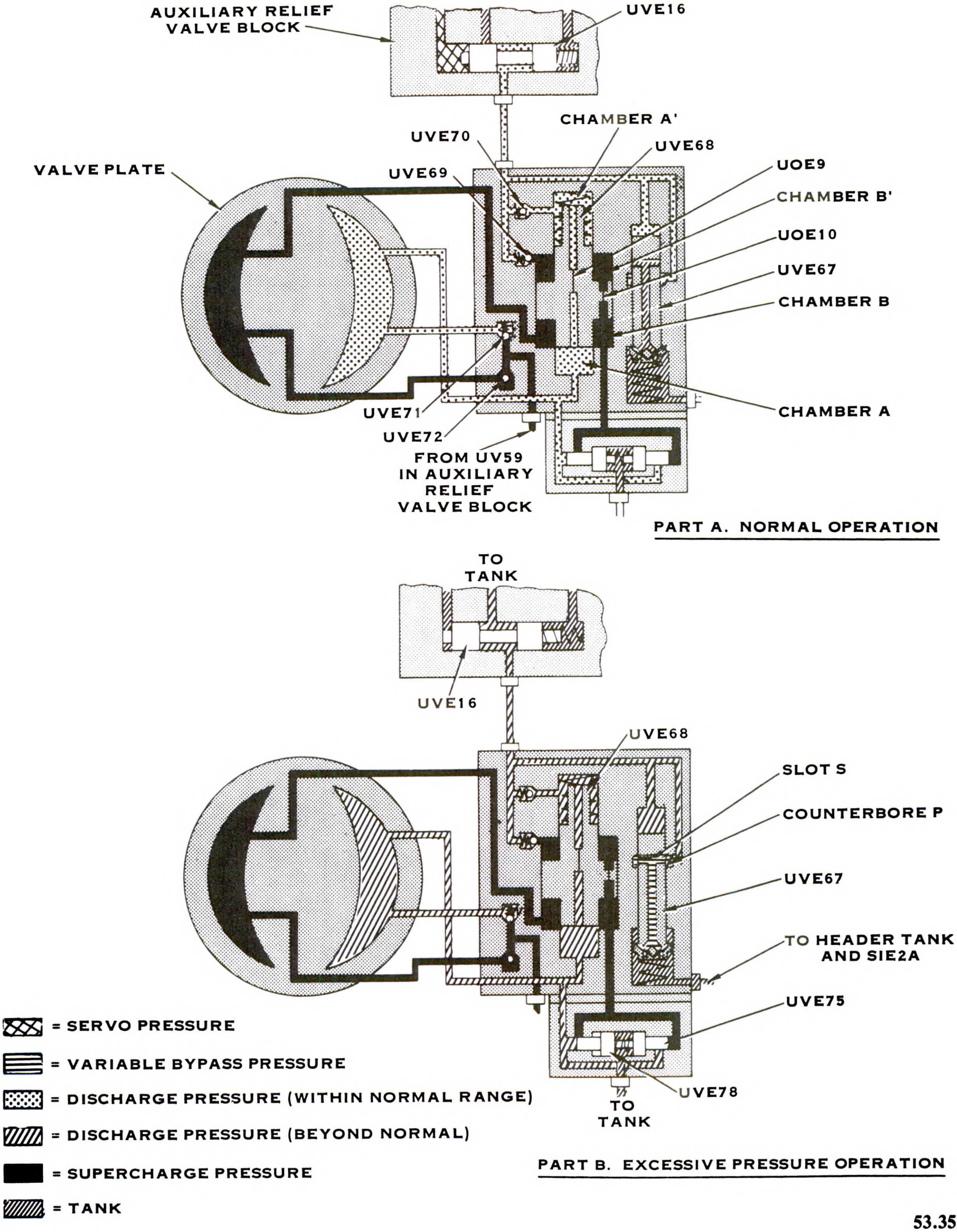
SAFETY RELIEF VALVE

The elevation safety relief valve (fig. 5-21, view A) is a compound relief valve consisting of a pilot



84.41

Figure 5-20.—CAB unit (mechanical schematic).



53.352

Figure 5-21.—Safety relief valve operation.

valve UVE67, main relief valve UVE68, and four check valves (UVE69, UVE70, UVE71, and UVE72). There are two springs in the valve block which hold UVE67 and UVE68 seated until an excessive pressure condition occurs. There are two control orifices in UVE68 that prevent pressure buildup in the CAB unit during normal operation.

The safety relief valve has two functions:

1. It limits hydraulic pressure buildup in the high pressure output line of the A-end. (It operates in conjunction with pressure cutout switch SIE2A.)
2. It prevents pump cavitation by porting supercharge fluid to the low pressure return line of the A-end (compensating for fluid lost through slippage and leakage).

Operation of Safety Relief Valve

The direction of the A-end stroke determines which chamber of the valve plate ports A-end output (high pressure) fluid and which ports return (low pressure) fluid. The operation of the main relief valve, however, is independent of the direction of stroke. Figure 5-21, view A, shows the valve plate feeding A-end output to chamber A and return fluid to chamber B of the main relief valve. The valve functions in the same manner when the fluid in chambers A and B are reversed.

Check valves UVE71 and UVE72 control the flow of supercharge fluid to the CAB unit valve plate. Check valves UVE69 and UVE70 allow the flow of A-end output to UVE67 while preventing its flow into the return passages. During normal operation, A-end discharge fluid pressure holds one check valve open and the other closed. With A-end discharge fluid in chamber A', UVE70 opens a passage leading to pilot valve UVE67 in the safety relief valve block, to pilot valve UVE16 in the auxiliary relief valve block, and to the reverse side of UVE69. When the discharge fluid pressure is in chamber B', UVE69 opens chambers B' to UVE67, to UVE16, and to the reverse side of UVE70.

The plunger of the main relief valve UVE68 has four faces of identical effective areas. These areas are in chambers A, A', B, and B'. It also has identical orifices UOE9 and UOE10 which restrict the flow of fluid from chambers A to A' and from B to B'. When no fluid is flowing from the lower chambers to the upper chambers, the hydraulic pressure in all four chambers is equal. When discharge fluid pressure in A and A' are equalized and supercharge fluid pressure in B and B' are equalized, the only effective force is the initially compressed mainspring which holds the plunger seated.

When either UVE67 or UVE16 opens to tank, it also opens chambers A' and B' to tank. Any fluid flow through UVE67 or UVE16 must come from the valve plate through the two orifices and UVE70 and UVE69. The fluid pressure in the upper chambers drops below that in the lower chambers because of the orifices. When this occurs, the fluid pressure overcomes the force of the mainspring and UVE68 plunger unseats. Now, with UVE68 unseated, A-end discharge fluid in chamber A bypasses to chamber B and into the return (low pressure) passage of the valve plate.

During normal operation the conditions affecting the safety relief valve are as follows:

1. The A-end is on stroke.
2. Valve UVE16 in the auxiliary relief valve block is blocking discharge fluid.
3. The power-off brake is released.

Under these conditions, UVE68 is in hydraulic balance and its plunger is seated. Any variation in the load on the CAB unit varies the discharge pressure in the valve plate. This variation acts on the top of UVE67.

During normal operations, however, the fluid pressures do not exceed the preload of the UVE67 spring. Accordingly, UVE67 never bypasses fluid to tank. With no line open to tank, the main relief valve cannot unseat.

During excessive pressure operation (fig. 5-21, view B), the conditions affecting the safety relief valve are as follows:

1. The A-end is on stroke.
2. Either the gun barrel elevates or depresses into a physical obstruction or the brake sets as the result of a power failure. (The physical obstruction could be something on deck or it could be the elevation or depression buffer.)

ANSWER TO QUESTION Q12.

A12. 15.

To protect the valve plate against high temperatures developed during prolonged bypassing (more than 0.9 second), the pressure cutout switch SIE2A in the tank line of UVE67 shuts down the electric motor. The preload of the UVE67 spring determines the hydraulic pressure required at the top of UVE67 to unseat its plunger and, in turn, to bypass discharge fluid to tank through the slot in the plunger. Thus, the two valves that determine when the main relief valve unseats are UVE67 and UVE16.

When the gun elevates or depresses into a physical obstruction, pressure in the discharge passage of the valve plate rises beyond the bypass limit of the safety relief valve. This abnormally high pressure offsets the preload of the UVE67 spring and shifts the UVE67 plunger downward to bring slot S and counterbore P into line-to-line orientation. Further increase in pressure on the top of UVE67 shifts the plunger farther down to permit a proportional flow of discharge fluid to tank through counterbore P and slot S.

When the resulting flow causes the pressure in the lower chambers of UVE68 to offset the force of the mainspring, the UVE68 plunger unseats. Thus the safety relief valve keeps the discharge pressure in the CAB unit within the bypass limit.

Q13. How many functions does the safety relief valve have?

SERVO AND SUPERCHARGE SUPPLY SYSTEM

The servo and supercharge supply system consists of a servo and supercharge pump, an auxiliary relief valve block, a servo accumulator, a charging valve, and a pair of fluid filters. This system shares the main tank and the header tank with the upper accumulator system.

Servo and Supercharge Pump

The servo and supercharge pump is mounted on the aft end of the right trunnion support and is driven by the elevation electric motor. This dual output gear pump supplies servo fluid to control both CAB units (train and elevation) and also the supercharge fluid to replenish CAB unit slippage. Except for being larger, this pump is similar in design to the servo pump used on the 5"/54 Mk 42 Mods 9 and 10 gun mounts.

Auxiliary Relief Valve Block

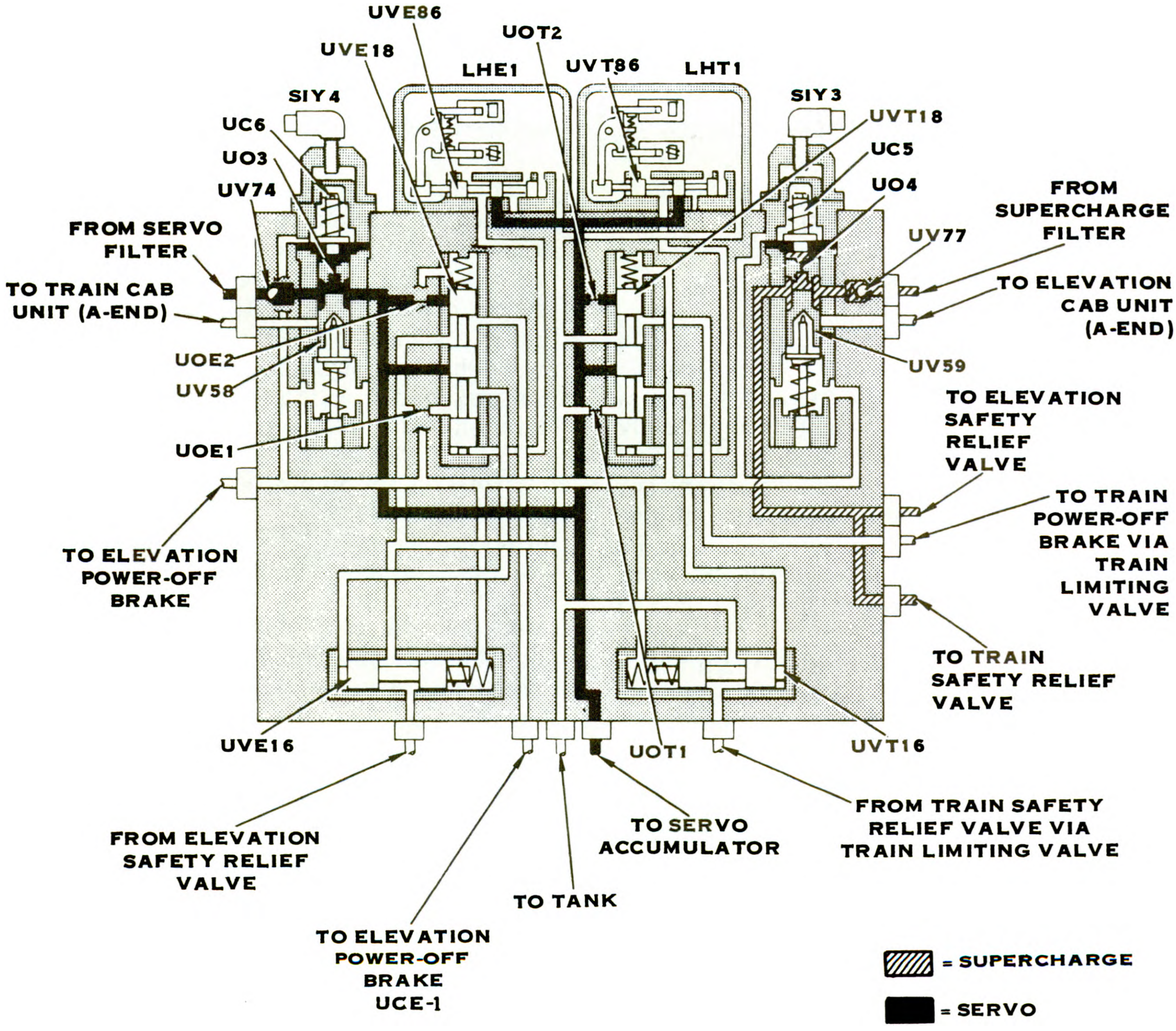
The auxiliary relief valve block (fig. 5-22) is mounted in the middle of the right trunnion support. Its purpose is to limit supercharge fluid pressure to 150 psi, limit servo fluid pressure to 450 psi, control the operation of the power-off brake, indicate by means of switches the availability of supercharge and servo fluid pressures, and provide a flow of fluid to cool the elevation and train CAB units.

When the elevation electric motor is started, filtered supercharge fluid enters the valve block through check valve UV77 and is ported to the center of supercharge pressure relief valve UV59. From UV59, it ports to the train and elevation safety relief valves to replenish the transmission lines. As supercharge fluid builds up to its normal operating pressure of 150 psi, it forces UV59 downward against its spring and, through orifice UO4, forces supercharge pressure switch piston UC5 upward against its spring. When supercharge fluid reaches 150 psi, UC5 activates switch SIY3 indicating that supercharge fluid pressure is normal and, at the same time, UV59 moves down and opens a port that bypasses part of the supercharge fluid to the elevation CAB unit. Thus, UV59 maintains supercharge fluid pressure at 150 psi and bypasses the surplus fluid to circulate through, and cool, the elevation CAB unit.

Servo pressure relief valve UV58 functions in the same manner as UV59 to limit servo fluid pressure to 450 psi. Orifice UO3, piston UC6, and switch SIY4 function in the same manner as do orifice UO4, pressure switch piston UC5, and switch SIY3.

Servo fluid is ported to both train and elevation power-off brake release plungers UTE18 and UVE18, to the solenoid operated pilot valves UVE86 and UVT86, and to the servo accumulator. Surplus servo pump output is also ported by UV58 to circulate through, and cool the train CAB unit when servo fluid pressure reaches 450 psi.

Solenoids LHT1 and LHE1 located on top of the auxiliary relief valve block, set or release the power-off brakes and activate the safety relief


UVE86
UOT2
UVE18
LHE1
UVT86
LHT1
SIY4
SIY3
UVT18
UC6
UC5
UO3
UO4
UV74
FROM SUPERCHARGE FILTER
FROM SERVO FILTER
UV77
TO TRAIN CAB UNIT (A-END)
TO ELEVATION CAB UNIT (A-END)
UOE2
UV59
UV58
TO ELEVATION SAFETY RELIEF VALVE
UOE1
TO TRAIN POWER-OFF BRAKE VIA TRAIN LIMITING VALVE
TO ELEVATION POWER-OFF BRAKE
TO TRAIN SAFETY RELIEF VALVE
UVE16
UOT1
UVT16
FROM ELEVATION SAFETY RELIEF VALVE
TO SERVO ACCUMULATOR
FROM TRAIN SAFETY RELIEF VALVE VIA TRAIN LIMITING VALVE
TO TANK
TO ELEVATION POWER-OFF BRAKE UCE-1
▨ = SUPERCHARGE
■ = SERVO

53.353

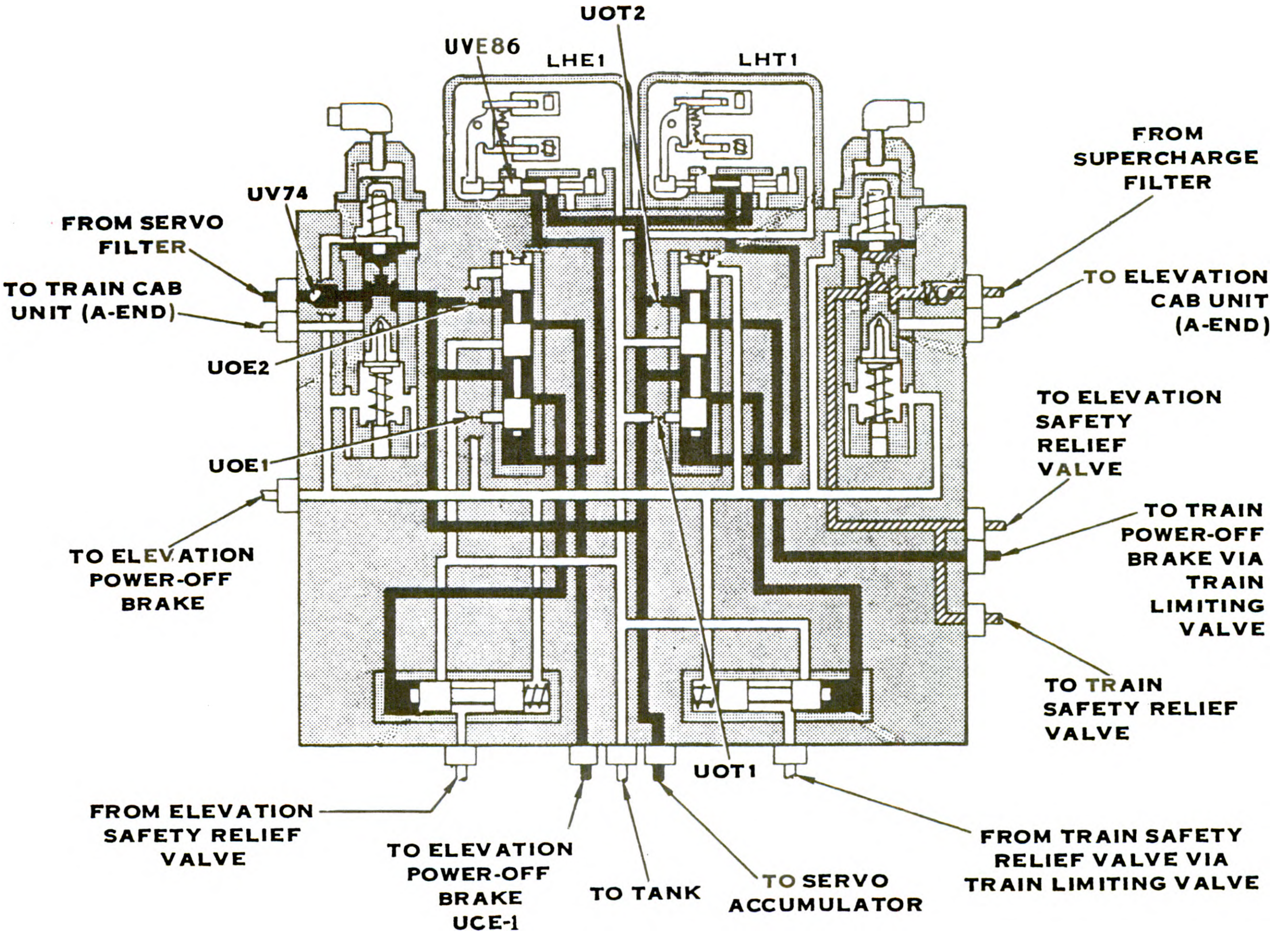
Figure 5-22.—Auxiliary relief valve block (elevation motor started).

valves. When LHE1 energizes (fig. 5-23), UVE86 shifts to the left, porting servo fluid to the bottom of UVE18. As UVE18 moves upward against spring tension, its lower land closes a port to tank and its upper land opens a servo fluid line to power-off brake release piston UCE1. At the same time, the center land of UVE18 opens another servo fluid line to the left end of pilot valve UVE16, shifting it to the right and blocking the A-end output from the elevation safety relief valve. With the A-end output blocked by UVE16, the safety relief valve seats, allowing the A-end output to build up pressure to the B-end.

When the elevation power drive is stopped, LHE1 deenergizes and shifts UVE86 to its neutral position, porting the fluid on the bottom of

ANSWER TO QUESTION Q13.

A13. Two.


UOT2
UVE86
LHE1
LHT1
FROM SUPERCHARGE FILTER
UV74
FROM SERVO FILTER
TO TRAIN CAB UNIT (A-END)
TO ELEVATION CAB UNIT (A-END)
UOE2
TO ELEVATION SAFETY RELIEF VALVE
UOE1
TO TRAIN POWER-OFF BRAKE VIA TRAIN LIMITING VALVE
TO ELEVATION POWER-OFF BRAKE
TO TRAIN SAFETY RELIEF VALVE
UOT1
FROM ELEVATION SAFETY RELIEF VALVE
TO ELEVATION POWER-OFF BRAKE UCE-1
TO TANK
TO SERVO ACCUMULATOR
FROM TRAIN SAFETY RELIEF VALVE VIA TRAIN LIMITING VALVE

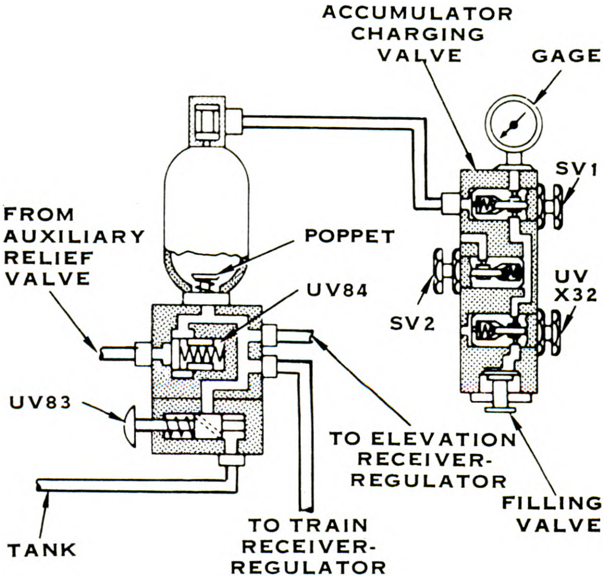
53.354

Figure 5-23.—Auxiliary relief valve block (power-off brake released).

UVE18 to tank. This closes the servo fluid line and ports UCE1 to tank, setting the power-off brake. Pilot valve UVE16 then shifts to the left because the pressure on its left end is ported to tank and is spring loaded. This allows the safety relief valve to open and port A-end output to tank.

Servo Accumulator

The servo accumulator (fig. 5-24) maintains a reserve of servo pressure to meet peak demands for both the train and elevation power drives. Servo pressure enters the accumulator through a spring-loaded check valve, UV84. Valve UV84 prevents accumulator pressure from feeding back through the pump during shutdown. Fluid then ports to the accumulator flask and to the receiver-regulator of each power drive. The fluid reserve in the flask is held under pressure by the nitrogen charged bladder.


ACCUMULATOR CHARGING VALVE
GAGE
SV1
FROM AUXILIARY RELIEF VALVE
POPPET
UV84
UV X32
SV2
UV83
TO ELEVATION RECEIVER-REGULATOR
FILLING VALVE
TO TRAIN RECEIVER-REGULATOR
TANK

53.355

Figure 5-24.—Servo accumulator (schematic diagram).

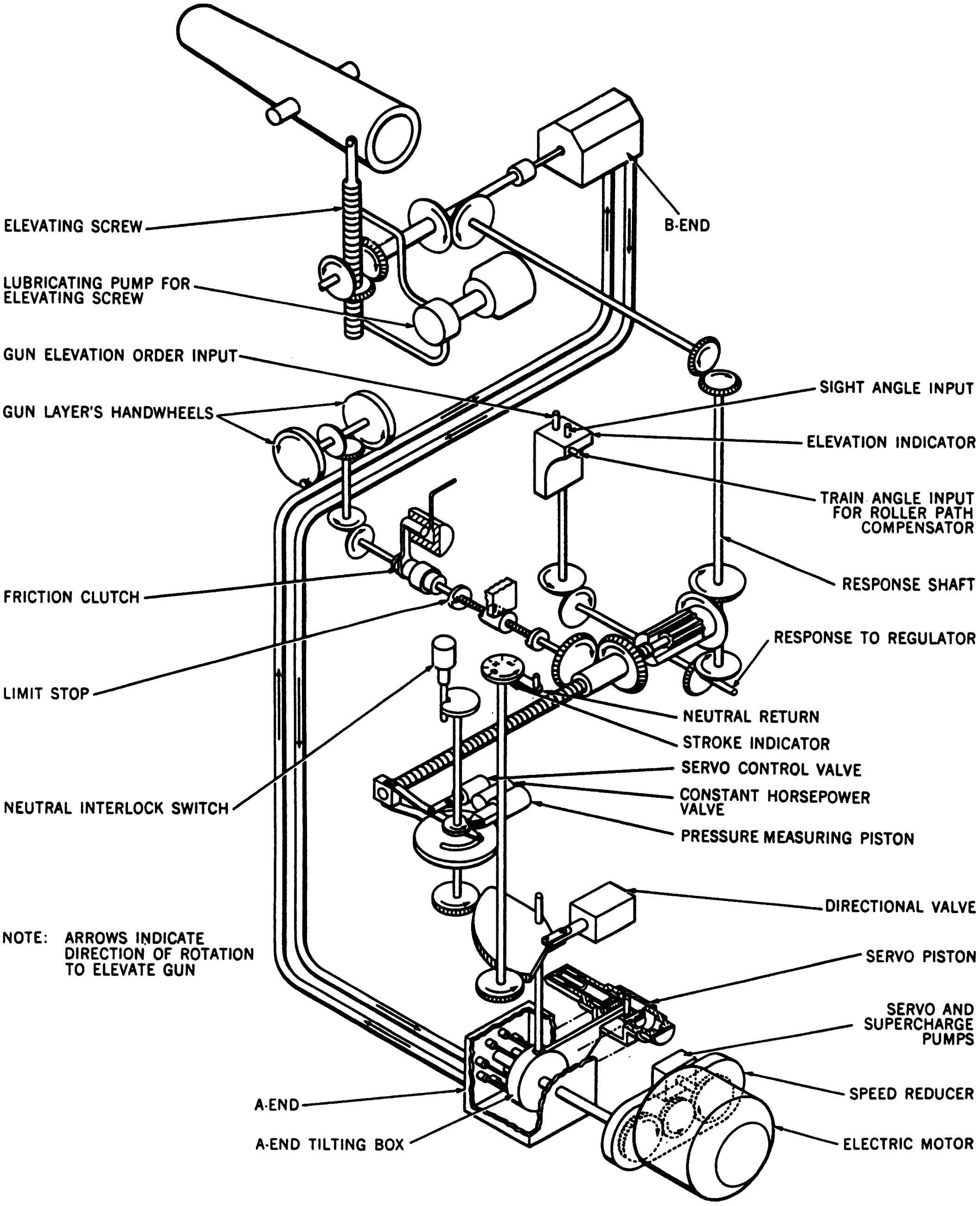
Q14. What is the purpose of a servo pump?

THE 16-INCH TURRET POWER DRIVE

Three separate elevation power drives are used to elevate and depress the 16-inch gun. There is one train power drive to move the turret right or left. These systems differ only in size and minor details. Only the elevation power drive will be described.

GENERAL DESCRIPTION

The elevation power drive consists of an electric motor, a speed reducer unit, A-end and B-end, a receiver-regulator, and a mechanical gear assembly. The electric motor, through the speed



53.367

Figure 5-25.—16-inch elevating gear Mk 5 Mod 0 (schematic arrangement).

reducer unit, drives the A-end of the hydraulic transmission at a constant speed. The A-end, in turn, drives the B-end and consequently, the elevating gearing at a speed and in a direction determined by the receiver-regulator. On the opposite side, the electric motor drives the auxiliary gear pump. Figure 5-25 shows the layout of the principal components of the 16-inch elevation power drive.

ELECTRIC MOTOR (16-inch Turret)

The elevation gear electric motor and speed reducer provide a constant speed input to the hydraulic transmission. The motor is a 440-volt squirrel cage induction motor rated at 60-horsepower. The motor has its output shaft at the forward end, with a direct drive coupling to the speed reducer.

SPEED REDUCER

The speed reducer, enlarged for clarity in figure 5-26, is driven by the electric motor and is mounted to the motor case by an integral flange of the speed reducer housing.

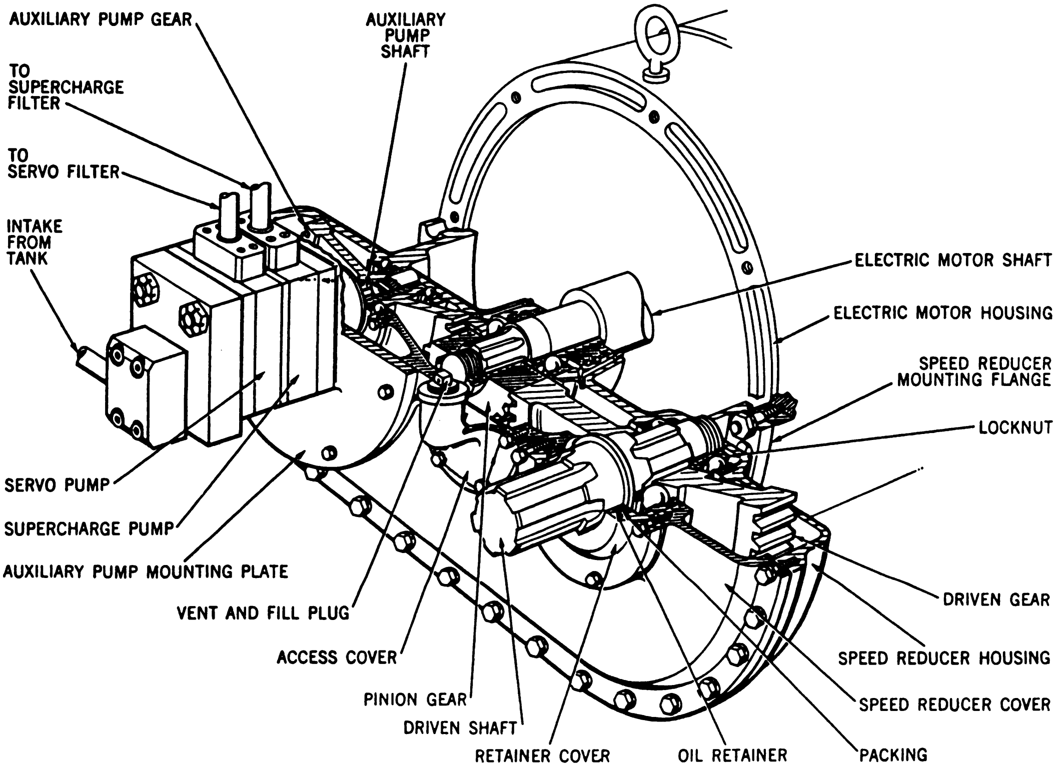
The pinion gear, driven by the electric motor, drives both the driven shaft (output shaft for the A-end pump) and the auxiliary pump shaft for the servo and supercharge pumps.

AUXILIARY PUMPS

The auxiliary pumps are mounted on the speed reducer housing. They are arranged as a tandem-driven assemblage of functionally independent pumps. Both are rotary gear-type pumps of identical design but of different capacities. The larger one is a servo pump that supplies the servo piston housing. The other is a supercharge pump that supplies hydraulic fluid to the main system.

Servo Pump

The intake of the servo pump is connected to the main supply tank. The pump discharges



53.368

Figure 5-26.—Speed reducer assembly (cutaway view).

through a duplex filter into the control selector and stroking system.

Supercharge Pump

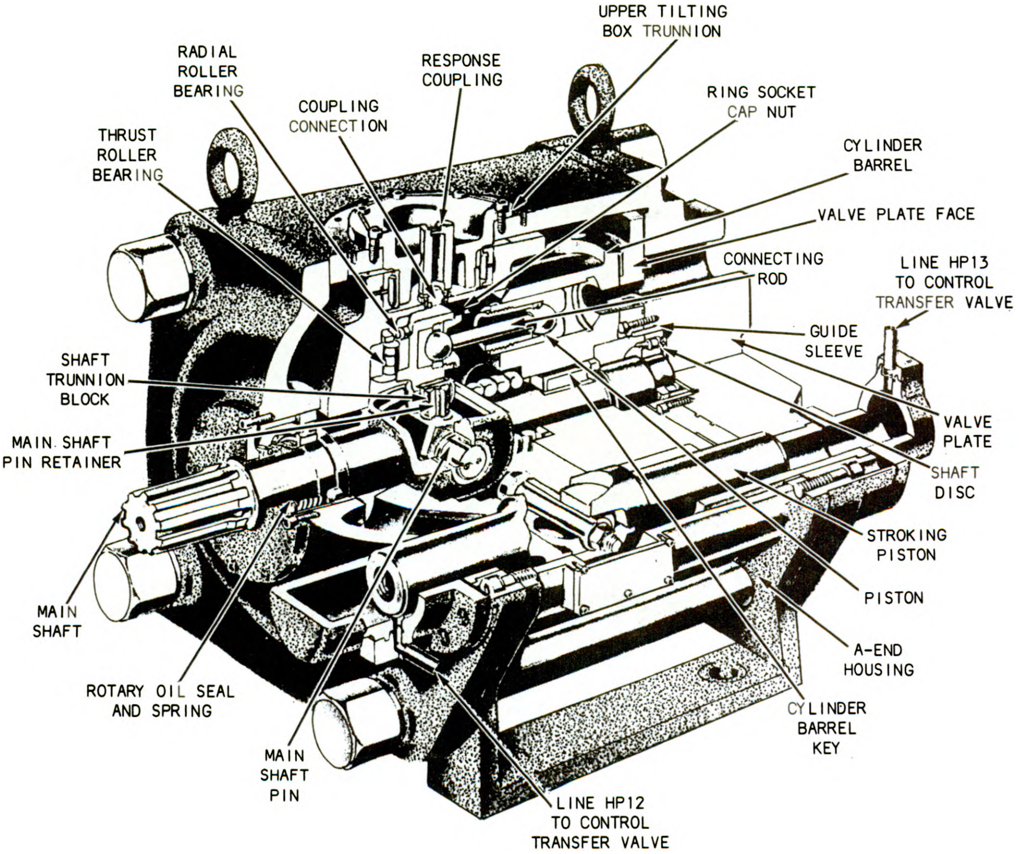
The intake of the supercharge pump connects to the main supply tank through a common connection with the servo pump. The supercharge pump discharges through a duplex filter into the main system relief valves and replenishing valves.

A-END

The A-end is a variable-displacement hydraulic pump driven by the electric motor and speed reducer. A square oil-tight case encloses the A-end (fig. 5-27). The case assembly consists of a valve plate, rotating group, and tilting box.

Valve Plate

The valve plate is stationary and forms one end of the A-end case. The inner surface of the plate is a finished surface against which the cylinder barrel rotates. This surface has two grooves, called valve plate ports. These ports connect with the power transmission pipes between the A-end and the B-end.



53.370

Figure 5-27.—Elevating gear A-end assembly (cutaway view).

ANSWER TO QUESTION Q14.

A14. Supplies servo fluid to train and elevation CAB units.

Rotating Group

The rotating group consists of a drive shaft, a socket ring and pistons, and a cylinder barrel. The drive shaft supports and drives the socket ring, pistons, and cylinder barrel. Shaft rotation is transmitted by a universal joint formed by a trunnion in the shaft yoke.

Tilting Box

The tilting box controls the output of the A-end according to the hydraulic pressure from the receiver-regulator.

B-END

The B-end is a fixed-displacement hydraulic motor. This motor, which encompasses the forward portion of the transmission, is driven by hydraulic pressure from the A-end. The B-end consists of a valve plate, rotating components, and an angle box. The valve plate and angle box of the B-end are mounted to the B-end foundation.

Valve Plate

The valve plate acts as a cover for one end of the B-end. The valve plate contains hydraulic passages which connect with the two power transmission pipes from the A-end. The valve plate also holds the ball bearing assembly in which one end of the main shaft rotates.

Rotating Group

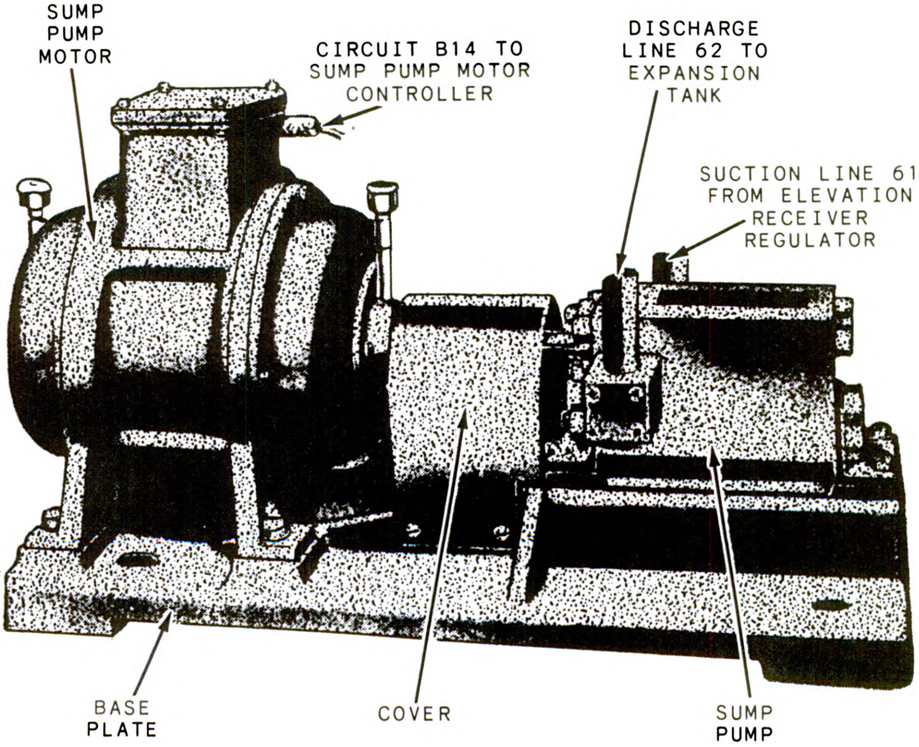
The rotating group of the B-end is basically the same as the rotating group of the A-end. The cylinder barrel is held against the valve plate by a spring which backs up against a flange on the main shaft.

Angle Box

The angle box, in which the socket ring rotates, is permanently tilted at an angle of 20 degrees. The pistons and connecting rods reciprocate through one full stroke each time the main shaft makes one revolution. The socket ring rotates in radial-thrust roller bearings.

SUMP PUMP

The sump pump is a separate motor-pump set located near the A-end (fig. 5-28). Hydraulic fluid


SUMP PUMP MOTOR
CIRCUIT B14 TO SUMP PUMP MOTOR CONTROLLER
DISCHARGE LINE 62 TO EXPANSION TANK
SUCTION LINE 61 FROM ELEVATION RECEIVER REGULATOR
BASE PLATE
COVER
SUMP PUMP

53.369

Figure 5-28.—Elevation receiver regulator Mk 10 Mod 0 sump pump.

and drainage from the receiver-regulator valve block returns to a sump tank from which the fluid is pumped into the expansion tank. During normal operations, the sump pump runs whenever the main electric motor is running. Whenever the fluid level drops too low, the float-operated sump pump valve opens to ensure an adequate supply of fluid to the pump at all times.

Q15. How many elevation power drives are used on the 16-inch turrets?

Q16. The supercharge pump supplies fluid to what system?

MAINTENANCE

Hydraulic power drives are rugged, proven machines. Properly inspected and installed, they will operate for an indefinite period of time. Strict adherence to the instructions in the maintenance publications will help the equipment to retain its design characteristics of power, speed, and control, and eliminate extensive repairs and costly replacement.

Hydraulic systems which perform satisfactorily and show no evidence of sludge, rust, or malfunctions should not be opened. All cover nuts should be kept tightly secured to discourage removal without good reason.

This does not mean that casualties will not occur in your equipment, but when they do happen, you should reach first for your OP, not a wrench. Correct casualty analysis can be made only by someone with a thorough knowledge of the operation of the equipment.

Many hydraulic power drives have seen years of service. Because of constant use, working parts may become worn and springs will become weakened. Hydraulic transmission fluid will become contaminated with moisture and foreign material. Vibrations, over a period of time, cause copper tubing to crystallize and crack. This condition is especially prevalent in smaller tubing near flanges.

To combat these troubles and to prevent malfunctions from developing to a stage where they will seriously affect mount operation, a routine maintenance program, including daily checkoff, is essential.

FLUID LEVEL AND PRESSURE CHECKS

Frequent checks should be made to assure proper fluid level in the system. Impress on the personnel working for you, especially the strikers, the hazards of neglecting the hard-to-get-to spots. An example of such a place is the dipstick on the 5"/38 twin mount elevation main reduction gears. The removal of a plate for access to the dipstick takes much less time than removing this heavy assembly for repairs.

The various fluid pressures present in a hydraulic power drive—servo pressure, response pressure, and supercharge pressure—must be maintained at their specified levels for proper mount operation. The OPs state these pressures, giving the correct values in psi for each.

In the event of a casualty, you may be required to take readings of these pressures to make a comparison with the correct value as listed in the OP.

Gages are furnished you for this purpose. Connection plugs for inserting the gage into the suspected system are located at filters, pump outlets, and valve blocks.

PUMPS

As a rule, pumps in hydraulic power drive systems require little maintenance other than proper lubrication and a clean hydraulic system in which to operate. In addition to the obvious failure of a pump to deliver its designed output because of worn or broken parts, unusual noise and overheating are also signs of trouble. Many times the cause of these two symptoms will not be in the pump itself. A frequent cause of noise is the failure of fluid to reach the pump. This condition can be caused by low fluid level in the reservoir or by clogged lines or filters. Since the pump depends upon liquid for lubrication, failure of the fluid supply will soon cause the pump to heat up, and probably cause parts to bind.

Another cause of abnormal noise is poor alignment between a pump and its driving mechanism. This condition will cause worn parts and possibly leakage, reducing the pump's efficiency.

Pounding or rattling noises in axial piston pumps may be unavoidable due to a partial vacuum produced in the active system during high speed operation or under heavy loads. It should, however, stop when the load is reduced. If not, you will have to bleed air from the system.

Use special care when you reassemble a rotary gear-type pump. The rotors operate in a pump casing or body. End plates enclose the rotors on each side. When tightening the screws holding the sections together, use only moderate force. Make them just tight enough to allow free movement of the rotor with no leakage.

Q17. What causes copper tubing to crystallize and crack over a period of time?

HYDRAULIC FLUID

The fluids specified for use in hydraulic power drives are currently of the petroleum-base type, containing additives to improve certain chemical and physical properties.

These fluids must be chemically stable and nonfoaming. They must have a high viscosity index, adequate lubricating qualities, and a low pour point. They must have no harmful effects on, and not be affected by, the metal parts of the system.

Fluid MIL-F-17111 is the power transmission fluid generally approved for hydraulic power drives. While its lubricating properties make it adequate as a lubricant within hydraulic transmission systems, it is not a general-purpose lubricating oil. It should never be used on any parts or other mechanisms for which other lubricants are prescribed.

Certain individual power drive components, such as reduction gears and gear brackets, require fluids with different characteristics. This is because they operate under different loads, speeds, etc. OD 3000 and lubrication charts indicate the approved fluid, frequency of application, and approved substitutes. They also contain additional information relating to draining, filling, and other maintenance functions in conjunction with lubrication.

Setting standards for hydraulic fluids, and outlining their proper service applications, is the responsibility of NAVSEA. It is your responsibility, however, to maintain the condition of the fluid when it is placed in your equipment.

A hydraulic system must be substantially free of contaminants such as water, dirt, insoluble products resulting from oxidation, corrosion products, and metal particles. These contaminants may cause damage to working surfaces, the sticking of operating components, or the clogging of filters, resulting in erratic performance or complete failure of the equipment.

Q18. Who sets the standards for hydraulic fluids?

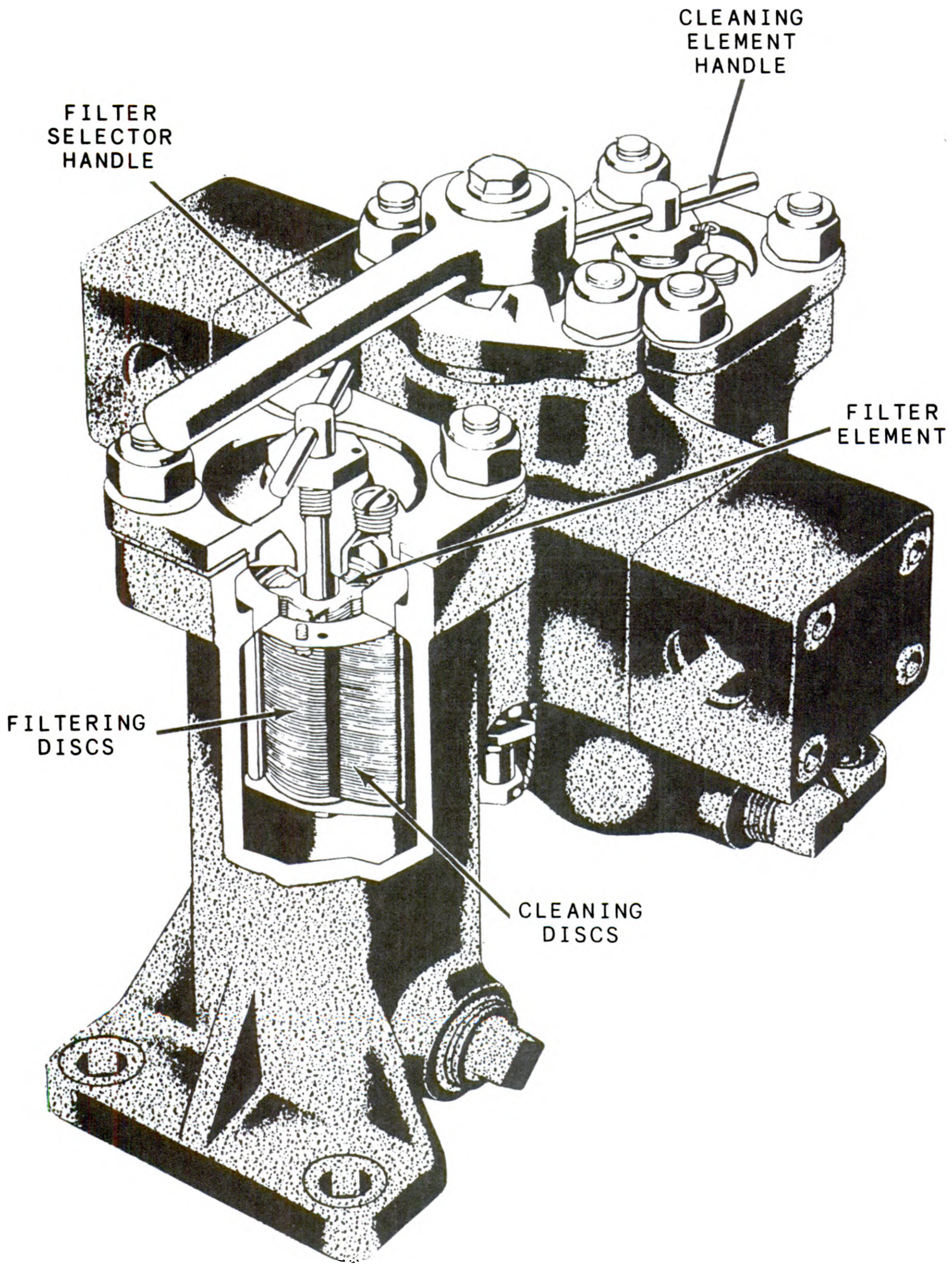
FILTERS

Filters used in hydraulic systems serve mainly to remove insoluble particles from the fluid. The type of filter used in a particular system depends on the size and type of the smallest particle to be removed. A full-flow filter is one which filters all of the fluid which passes through the pumps. Such a filter is provided with a relief valve to allow bypassing of the fluid if the filter element is clogged. A bypass filter is one which filters only a portion of the fluid passing through a pump. As a rule, bypass filters are designed to remove finer particles than the full-flow type.

Some power drives use disposable cartridge-type filters. These filters require no maintenance, only occasional replacement of the cartridge.

Figure 5-29 shows a full-flow filter of the metal plate type. It is made up of metal discs through which the fluid is filtered. Two filter elements are mounted on a common inlet and outlet manifold. A hand-operated lever permits one or the other of the elements to be placed in use. A self-cleaning device consisting of blades which can be rotated between the cleaning discs is incorporated. Sludge removed from the elements in this manner collects at the bottom of the unit, and frequently should be drained out.

This filter can be cleaned by removing the filter element from the case. Back off on the stud screw at the base of the element enough to permit some looseness between the discs. Flush element thoroughly with an approved fluid.



53.76

Figure 5-29.—Replenishing oil filter (5″/38 twin mount).

ANSWER TO QUESTIONS Q15 THROUGH Q18.

A15. Three.

A16. Main system.

A17. Vibration.

A18. NAVSEA.

An example of the other type of filter (bypass) is shown in figure 5-30. This filter consists of a cylinder containing a filter element made up of a number of packs of perforated paper discs. Spring action maintains a uniform pressure on each of the packs. Fluid passes from the outside of the pack (where foreign matter is deposited) to the center passage, and through the outlet at the head of the filter.

The bypass filter is so designed that the head, with all the filter packs attached, can be lifted as a unit from the body of the filter. To clean this type of filter, remove the element and connect a low pressure air supply to the fluid outlet of the system. This allows the air to blow back through the element. When a white foam appears along the entire length of the pack, it is clean.

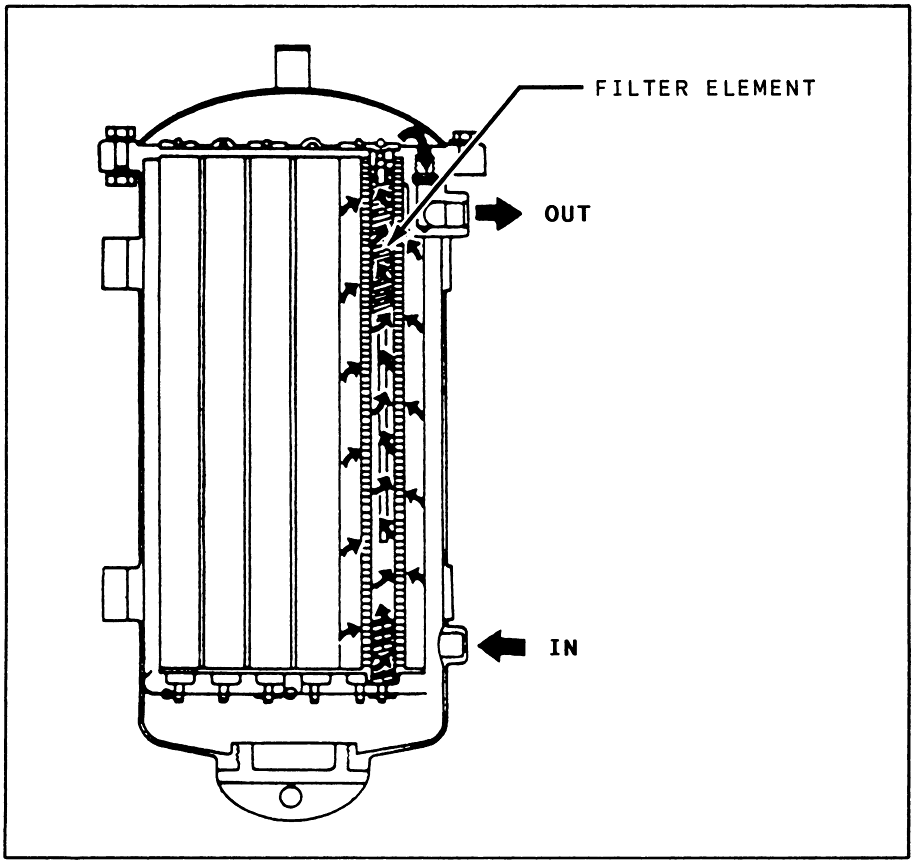
Q19. What method is used to clean a bypass filter?

FLUSHING AND FILLING THE UNIT

The transmission system of the power drive should be flushed and refilled with new fluid whenever any of the following conditions exist:

1. When tests (usually performed by a repair ship or shipyard) indicate that the fluid has oxidized and become so acid that it is no longer suitable for use.
2. When examination of contaminants removed from filters and low points in the system reveals the presence of corrosion or an excess of metal particles.
3. When a condition exists which necessitates cleaning of filters more often than once a week.
4. When new or repaired components are placed in a system.

Listed in OD 3000 are several approved flushing fluids. In the interest of economy,



53.77

Figure 5-30.—Auxiliary bypass filter.

however, reclaimed fluids should be used for this purpose.

While being flushed, hydraulic systems can be operated to raise the temperatures of the fluid.

Immediately after the warmup period, the system should be drained by opening all drain outlets.

Care should be taken when refilling the system with new fluid. Foreign matter is most likely to be introduced in the system during this operation. Dirt and chips can be introduced into a system through drain plugs, filler caps, or hose nozzles.

Never put fluid into a system without first passing it through a 200-mesh screened funnel. Never use cloth or rags to filter hydraulic fluid. Examples of good and bad practices in performing this operation are displayed in figure 5-31.

Q20. How should hydraulic fluid be filtered when it is put into a system?

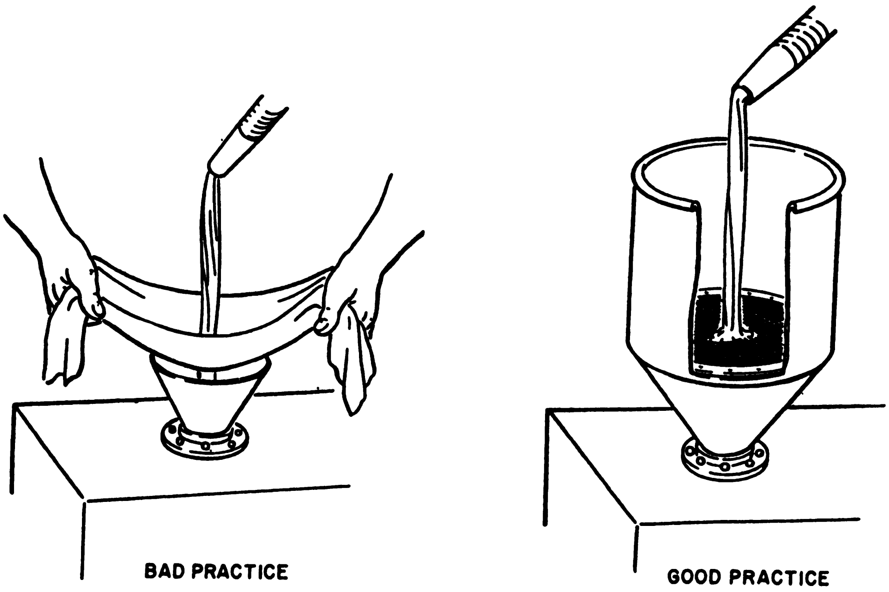
ADJUSTMENTS

Initial adjustments of the power drive are made at the time of installation with the aid of special gages and instruments. Subsequent adjustments aboard ship should be undertaken only after competent personnel have determined that such adjustments are necessary. For detailed instructions for accomplishing necessary adjustments, you must refer to the appropriate OP for the equipment.

SAFETY

The following safety precautions apply to all hydraulically operated ordnance equipment.

1. Always stop motors before working on equipment. If it is necessary to observe equipment in operation, stand clear of moving components.
2. Do not operate equipment without ensuring that all personnel are clear of moving components.
3. Whenever any motion of a power-driven unit is capable of inflicting injury on personnel or material not continuously visible to the person controlling such motion, the officer or petty officer who authorizes the unit to be moved by power shall, except at general quarters, ensure that a safety watch is maintained in areas where such



Fig'ure 5-31.—Filling the hydraulic system.

ANSWER TO QUESTION Q19.

A19. Low pressure air.

injury is possible both outside and inside the unit, and shall have telephone or other effective voice communications established and maintained between the station controlling the unit and the safety watch. These precautions are applicable to all types of ordnance and, if more than one safety watch is used, the station controlling the ordnance shall obtain an "all clear" report from each safety watch before starting any motors.

Each safety watch shall keep the assigned area clear and, if unable to do so, shall immediately report the area fouled, and the controlling station shall promptly stop the unit until all is clear.

4. Personnel shall not perform repairs or adjustments on energized mechanical or electrical equipment capable of inflicting injury except in cases where the repair or adjustment cannot be accomplished with the equipment deactivated. When such repairs or adjustments must be performed on energized equipment, one additional person who is familiar with procedures for emergency deactivation of the equipment, and capable of rendering aid, shall be stationed nearby for the duration of the repairs and adjustments.

5. A danger circle shall be established around power-driven armament installations, such as guns, gun turrets, directors, launchers, etc. The minimum criteria for such circles are as follows:

a. The danger area shall be encircled with a painted red line 4 inches wide. The inside of the red line shall be 18 inches from the maximum rotating projection of the mount, director, or launcher structure. Gun barrel muzzles or missile extension arcs may be used to determine danger circle areas if considered appropriate.

b. The danger area shall be labeled "DANGER AREA" by painting 2-inch high white letters centered in the 4-inch wide red danger circle line. The danger area label shall be repeated around the circle on 4-foot centers, as practicable.

c. All of the ship's structure that comes in contact with the 4-inch wide red line and the vertical extension of the line to a height of 7 feet, shall be labeled "DANGER AREA" by painting 2-inch high red letters centered on the area and its extremities at a height of 5 feet from the deck.

6. Wipe up any spilled hydraulic fluid immediately. Do not allow the temperature of hydraulic fluid to exceed 190 °F.

7. An electrical spark generated near overheated hydraulic fluid can cause a fire or an explosion.

8. If clothing becomes drenched with hydraulic fluid, change into dry clothing immediately. When in prolonged contact with the skin, hydraulic fluid can injure health.

9. Accumulator flasks are charged with nitrogen or compressed air, depending on the type of system installed. If nitrogen is not available, accumulators can be recharged with compressed air. However, all nitrogen accumulator systems must thereafter be purged of the compressed air and recharged with nitrogen as soon as it is available.

10. Never charge accumulator flasks with oxygen. An oxygen and hydraulic fluid mixture is extremely explosive.

Q21. The red danger circle line should be of what width?

SUMMARY

The power drive systems presented in this chapter as typical examples were all designed for the same purpose—to position a gun mount quickly and accurately. While component design features may differ considerably from system to system, a close study will, in many cases, show that although they may appear quite different, they have been designed to perform like functions in their systems. Some components may be so similar that the chief difference is only a matter of nomenclature. This chapter reviews a few examples of these similarities.

In the 5″/38 power drive, the break valves returned the A-end tilting box to neutral and stopped mount motion whenever control pressure was lost in the system. In the 5″/54 Mk 42 Mods 9 and 10, the Mk 45 Mod 0 and the 16″/50 power drives, we learned that the power-off brake gave us this same end result, only in a different manner.

The A-end titling box of the 5″/38 and 16″/50 power drives were positioned by the main cylinder and piston to control A-end output, while in the 5″/54 power drives this was done by two stroking pistons positioning a tilting plate and socket ring. Control and replenishing fluid pressures were regulated by independent relief valves in the 5″/38 and 16″/50 power drives. In the 5″/54 power drives, these pressures were regulated in the auxiliary relief valve block. All systems used a sump pump, although it was necessary for the train drive only in the 5″/54 systems.

So you see, one hydraulic drive system is, basically, not so very different from another. Once you have become familiar with one type, it should not be difficult to learn another.

REFERENCES

The following reference materials were used to develop the information presented in this chapter.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

5-Inch 38-Caliber Twin Gun Mount Marks 32 and 38 Description Operation and Maintenance, Third Revision, Naval Sea Systems Command OP 805, Feb 1982.

5-Inch 54-Caliber Gun Mount Mark 45 Mod 0 Description Operation and Maintenance, First Revision, Naval Sea Systems Command OP 3392, Vol. 1, Change 7, Dec 1985.

5-Inch 54-Caliber Gun Mount Mark 45 Mod 0 Description Operation and Maintenance, Second Revision, Naval Sea Systems Commnd, OP 3851, Vol. 1, Apr 1986.

16-Inch Three Gun Turrets, Description Operation and Maintenance, Naval Ordnance System Command, OP 769, Oct 1967.

Fluid Power, NAVPERS 16193-B, Naval Education and Training Program Development Center, Pensacola, Fla., 1970.

ANSWER TO QUESTIONS Q20 AND Q21.

A20. Filter through a 200-mesh screened funnel.

A21. 4 inches.

CHAPTER 6

HYDRAULIC CONTROL EQUIPMENT

In this chapter, we will study the equipment used to control hydraulic power drives. First, we take up the control equipment used with the 5"/38 gun systems. We will also explain the applications of electronic servo systems and discuss how servo amplifiers control power drives. At the end of the chapter, we have included some general pointers to aid you in maintaining the equipment.

5"/38 GUN MOUNT CONTROL EQUIPMENT

The major element in the control equipment for the 5"/38 twin mount is the indicator-regulator. This is a basically standard instrument, manufactured by the Ford Instrument Company, and is similar in principle to the automatic control instruments used in many other installations in the fleet. We will discuss this instrument here in some detail and show the operation of its components in each of the four different methods of control which can be used.

METHODS OF CONTROL

The 5"/38 twin mount has four methods of control: automatic, local, hand, and manual. The type of control to be used is selected at the pointer's and trainer's stations by means of a selector lever. Just above the control selector lever is a speed selector lever, used to engage one or the other of two sets of gears that give different values of gun movement for each turn of the handwheels. As the handwheels are not used in automatic, the speed selector will not affect that type of control. Refer to figure 6-1 as each of these control methods are discussed.

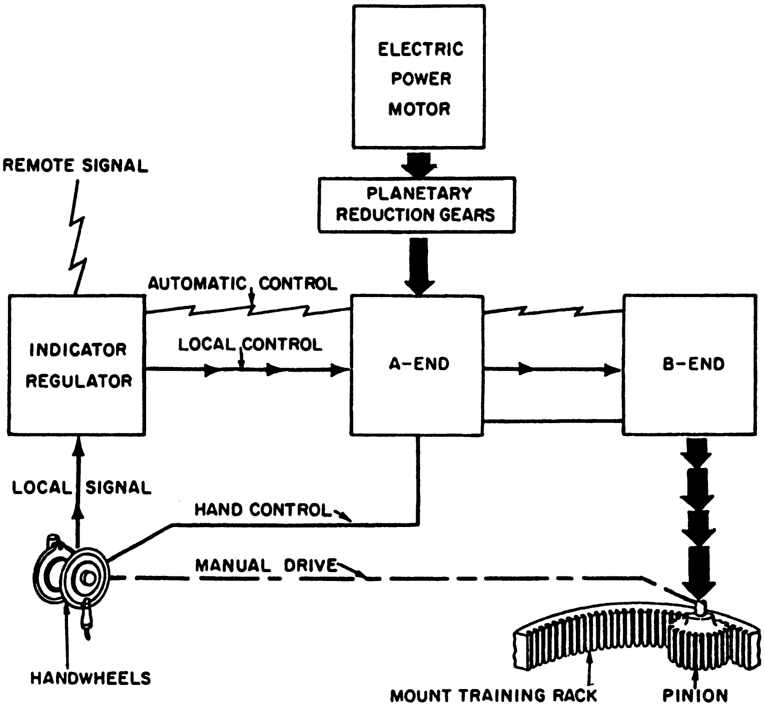


Figure 6-1.—Methods of control.

In automatic control, a signal from a remote source, received electrically at the indicator-regulator, controls hydraulic valves in the indicator-regulator. These valves control the output to the hydraulic pump (A-end). This, in turn, controls the output of the hydraulic motor (B-end), causing the guns to automatically follow the remote signal with negligible error.

In local control, the indicator-regulator performs the same function as in automatic except that a mechanical signal, produced by rotation of the handwheel assembly (local signal), is used instead of the electrical remote signal.

In hand control, the indicator-regulator is bypassed. The handwheels control, by direct means, the output of the hydraulic pump (A-end) and, consequently, the position of the guns.

In the above three methods, the hydraulic pump (A-end) is driven at a constant speed through the reduction gears by an electric motor. In case of failure of the electric motor or its source of power supply, a manual drive is provided.

In manual drive, the guns are moved directly by the effort applied to the handwheels. The handwheels are geared directly to the training racks, bypassing the entire power drive units. While the indicator-regulator does not operate in hand or manual, its indicator section continues to display gun mount positions (B-end response), and may continue to receive gun order position signals from the director.

INDICATOR-REGULATOR

The indicator-regulators are mounted on the handwheel drive assembly of the elevating and training gear system which they control. For simplicity, we will describe only the train indicator-regulator, showing the major differences between it and the elevation indicator-regulator as we go along.

The indicator-regulator components may be divided into three groups: indicating section, electrical equipment, and control equipment.

The indicator-regulator converts an electrical or mechanical signal into an equivalent power drive control action. In completely automatic control, the gun director sends electrical gun order signals to the indicator-regulator (in train only, parallax is also received and combined with gun order). The signals are received by devices in the regulator that compare the signal with the existing position of the gun. Any difference between the signal and the existing gun position shifts a hydraulic pilot valve away from its neutral position in a direction that causes the gun to drive toward the ordered position.

Displacement of the pilot valve from neutral causes movement of other valves in the indicator-regulator. Pressure is ported to the main (stroking) piston, causing it to move in the main cylinder. The main piston is mechanically connected to, and therefore positions, the tilting box of the A-end pump. This action causes delivery of a controlled amount of hydraulic driving power to the B-end motor.

As the B-end and the guns move, response is registered by the regulator and continuously compared with the gun order signal.

To better understand the operation of the indicator-regulator components in the different methods of control, let us examine them in more detail.

Indicating Section

This section gives the operator an indication of three things: (1) incoming gun order signals; (2) position of the guns; and (3) correction readings—parallax (train only) and roller path inclination (elevation only). Figures 6-2 and 6-3 show the indicating sections of the train and elevation indicator-regulators, respectively.

GUN ORDER INDICATORS.—Even though located in the same indicator-regulator, the indicating synchros (TRs) should not be confused with the control synchros (TRs), which actually control movement of the guns in automatic.

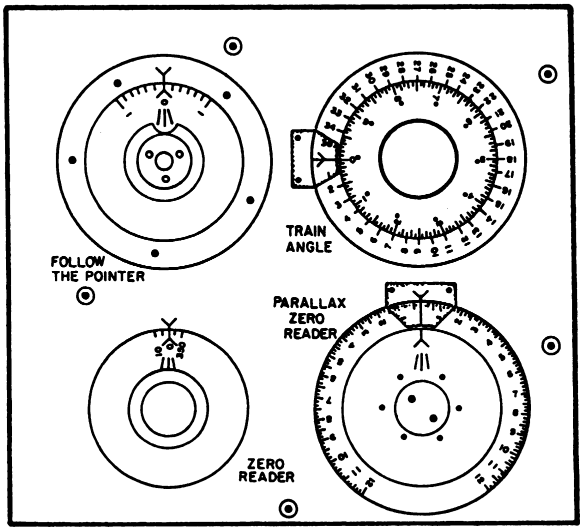
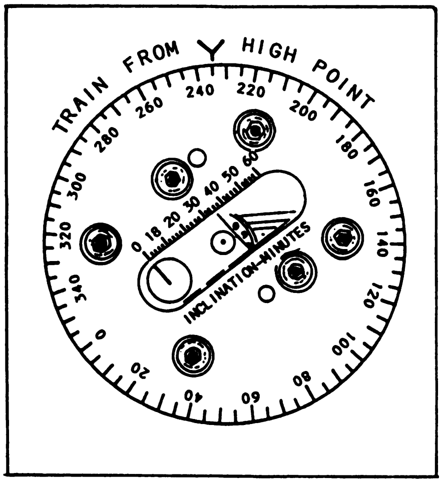


Figure 6-2.—Train dials.

ROLLER PATH INCLINATION DIALS



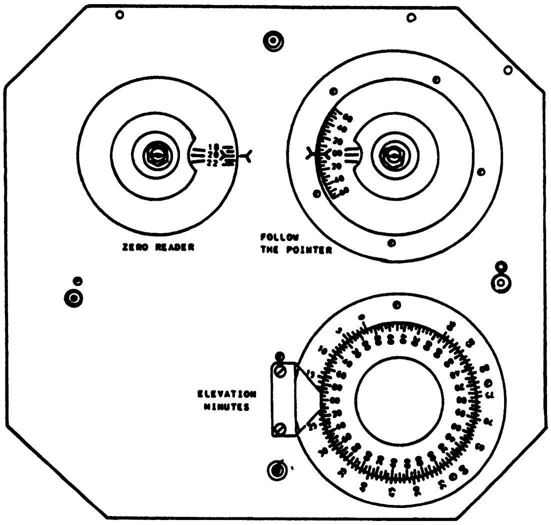


Figure 6-3.—Elevation dials.

Control synchros will be shown in more detail later in this chapter.

Gun order signals are received electrically from the director system by two synchro torque receivers (TRs). One is the fine indicating TR which rotates at 36 speed—that is, one revolution of the TR represents 10° of gun movement. The other TR, called the coarse indicating TR, rotates at 1 speed (one revolution of the TR represents 360° of gun movement).

The rotor of the coarse TR is attached to the zero reader dial. As the coarse TR rotates at 1 speed, the zero reader dial gives a coarse reading of the gun order signal. The stator of the coarse TR is rotated in an opposite direction to that of the rotor by mount response from the B-end. Because the rotor is carried with the stator, the zero reader dial will be aligned with the fixed pointer when the signal has been satisfied (that is, when mechanical response is equal to gun order).

The rotor of the fine indicating synchro is connected to the inner (disc) dial of the follow-the-pointer dial. The outer (ring) dial is connected to mechanical response. As the fine synchro motor rotates at 36 speed, the follow-the-pointer dial gives a very exact reading of gun order. But remember that the inner dial, being 36 speed, will be aligned with the ring dial index whenever the gun order signal differs from gun position by any multiple of 10°. Therefore, the fact that the indexes of the inner and outer dials are matched does not mean that the signal is satisfied unless the zero reader dial is matched with its index.

GUN POSITION INDICATORS.—Gun position is registered on a ring and inner dial assembly. These dials are driven by mechanical response from the B-end.

The dial assemblies are marked at their respective indicator-regulators as TRAIN ANGLE and ELEVATION MINUTES. The outer ring dials are rotated at 1 speed and are graduated in large increments. The inner dials are rotated 36 speed and give a more accurate reading, being graduated in smaller increments. Both inner and ring dials are read together against their fixed indexes for accurate readings.

CORRECTION INDICATORS.—Horizontal parallax is the angle formed in the horizontal plane, at the target, by the intersection of the lines of sight from each of two stations. These stations are, so far as you are concerned, the director and the gun mount. Most guns are located some distance from the director. Their lines of sight, if they are following the director perfectly, will be parallel and will not intersect at the target. Therefore, correction for parallax must be added to the gun train angle at each mount, so that the lines of sight of the gun and director will intersect at the target.

The parallax correction signal will be received at the indicator-regulator as unit parallax. Unit parallax is defined as a horizontal parallax correction of the magnitude and direction, for any given range and bearing, that would correct the train angle of an imaginary gun located 100 yards from the director. Change gears in the indicator-regulator reduce this signal to true gun parallax correction at each mount.

Parallax may also be introduced into the indicator-regulator manually by turning a handcrank. Selection of automatically or manually introduced parallax is made by shifting the two-position parallax handcrank knob.

On most indictor-regulators, the disk dial of the parallax indicator is marked with special graduations which facilitate the firing of illuminating projectile search spreads. By placing the parallax selector in MANUAL, and spacing the graduations at selected different settings for the various mounts, the desired spread of train angles can be obtained.

The roller path inclination indicator dial is found in the elevation indicator-regulator only. It indicates the inclination of the mount roller path from the horizontal, and the degree of mount train from the highest point of inclination. We will discuss this device in chapter 8.

STAR SHELL SIGNAL INDICATORS.—These indicators are merely lamps located in the face of the indicating section. They are lighted whenever the mount is ordered to fire illuminating projectiles and, therefore, this mount does not follow the same director signals as the rest of the battery.

Q1. Name the four methods of control for the 5"/38 twin gun mount.

Q2. One revolution of the coarse TR represents how many degrees of gun train?

Q3. How is parallax introduced into the indicator regulator?

Regulator Electrical Equipment

The major elements of the electrical equipment are TRs. In the indicating section of the indicator-regulator, they act to receive gun orders (and parallax) and indicate these orders by rotation of affixed disk dials.

In the control section of the indicator-regulator, the TRs act to receive gun orders from the director. By action of the TR rotors, the electrical signal is converted to a mechanical signal. The rotors mechanically operate the fine and coarse pilot valves.

Regulator Control Equipment

The control equipment of each indicator-regulator receives gun orders (electrically in automatic control and mechanically in local control), gun response, parallax corrections in train, and roller path tilt in elevation. The equipment combines these inputs to produce a variable flow of liquid to or from the regulator valve block and the main piston and cylinder. As a result of these actions, the A-end tilting boxes are positioned to control movement of the guns.

RELIEF CAM ASSEMBLIES.—The purpose of these assemblies is to permit the fine and coarse control TRs to continue to follow the gun order signals when the pilot valves have reached their limits of travel. The cylindrical relief cams are attached to the rotors of the fine and coarse control TRs respectively. A cam follower roller, held against each cam by a tension spring, connects the cam mechanically to its pilot valve. When a gun order signal rotates the rotors of either the fine or coarse TR, its cam and cam follower also rotate, thereby positioning the pilot valve. The cams are made so that their contact surfaces rise uniformly from a low point. When there is a sudden change in the position of the cam by the rotors, due to a reversal of gun order at high speed, it will momentarily cause the cam follower roller to leave the low point of the cam. The tension spring will return the roller to the low point of the cam fairly rapidly but, in the interim, the movement of the TR will be prevented from reacting too violently on the hydraulic control system.

DIFFERENTIAL CAM ASSEMBLY.—The differential cam assembly (fig. 6-4) compares gun order with gun position. It consists of a two-pronged fork (69) attached through the relief cam assembly to the rotor of the fine control TR, a three-fingered cam follower (52), and the differential cam (204). The differential cam is a hollow cylinder with three grooves curving up and around its inside surface. The fingers of the followers slide in these grooves and the prongs of the fork extend down through slots in the follower. A shaft extends downward from the follower and is secured to the fine pilot valve.

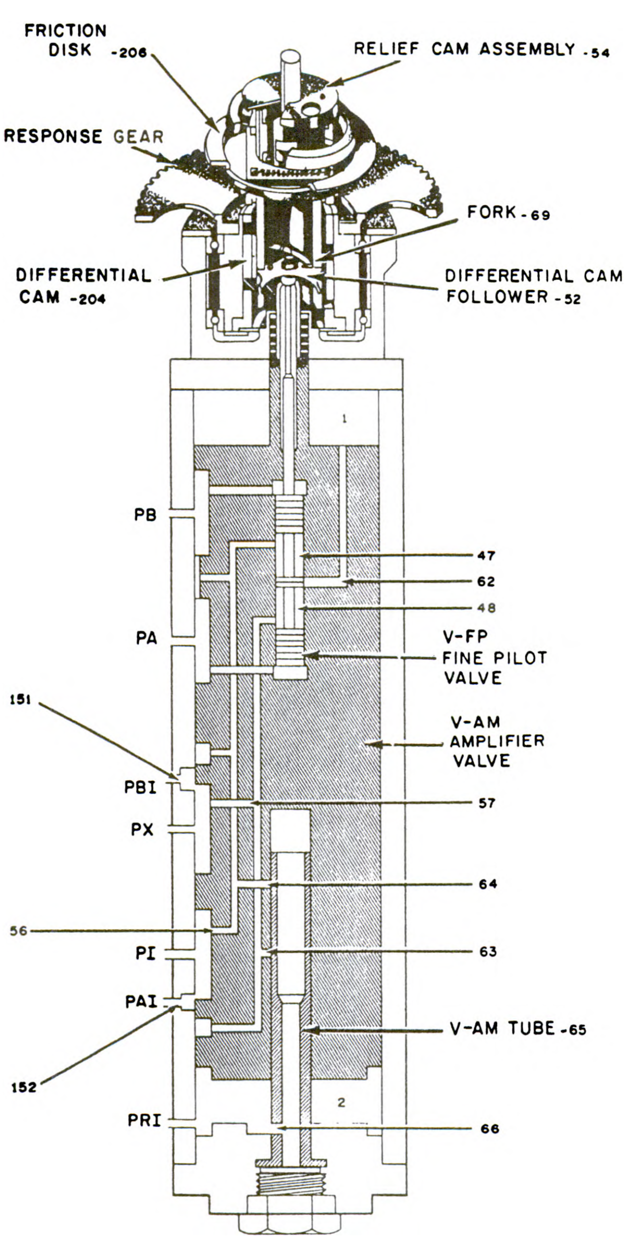


Figure 6-4.—Differential cam and amplifier valve assembly.

When either the fork or the cam is rotated, the follower will move either up or down inside the cam, depending upon the direction of rotation. Thus, reception of a signal by the fine control TR will cause the rotation of the fork and follower. When the follower moves up or down, the attached fine pilot valve is also moved.

Mount movement (response) is geared to the differential cam in which the follower moves. As the mount moves to follow a signal, the response moves the differential cam, displacing the follower and the fine pilot valve in a direction opposite to that produced by the signal. This action returns the fine pilot valve to neutral when the gun order has been satisfied.

Regulator Valve Block

The main control valves of the indicator-regulator are housed in the regulator valve block. These valves include the fine pilot valve, the amplifier valve, the acceleration valve, the main valve, and the selector valve.

FINE PILOT VALVE.—The fine pilot valve (V-FP), shown in figure 6-4, is positioned mechanically by the output of the differential cam (the difference between corrected gun order and actual gun position). It is located inside the amplifier valve and hydraulically controls its position.

AMPLIFIER VALVE.—The amplifier valve (V-AM), shown in figure 6-4, is controlled by, and has the same motion as, the fine pilot valve. With both the fine pilot valve and the amplifier valve in their neutral positions, the center land of V-FP closes the port leading from passage 62 to chamber 1 at the top of V-AM. (Pressures in chambers 1 and 2 are equal.)

A difference between gun order and gun position will result in an upward or downward movement of V-FP from its neutral position. Movement of V-FP upward ports chamber 1 to PX (exhaust), decreasing the pressure in chamber 1 and causing V-AM to move upward. Downward movement of V-FP from its neutral position would port chamber 1 of V-AM to PI, increasing the pressure in chamber 1 and forcing V-AM downward. The amplifier valve thus follows the movement of the fine pilot valve.

Movement of amplifier valve V-AM causes flow of liquid into or out of chamber 2. Movement of PRI liquid is important as it is directly concerned with control of the acceleration valve, main valve, main piston, and subsequently, the A-end tilting box.

Flow of oil into and out of chamber 2 is aided by the stationary amplifier valve tube. Upward movement of V-AM ports chamber 2 to PX through slot 65, port 63, and passage 57. More liquid then leaves the PRI system than the unaided upward movement of V-AM could draw in.

Downward movement of V-AM from neutral connects PI to chamber 2 through slot 65, port 64, and passage 56. Liquid from the PI system then enters the PRI system, increasing the amount of fluid flowing out of chamber 2 into the PRI system. Change in pressure in the PRI system is negligible when connected to PI or PX due to the narrowness of slot 65.

ACCELERATION VALVE.—To study the function of the acceleration valve and main valve, refer to figure 6-5. You will need to follow the pressure legend in this figure as this material is presented. The acceleration valve (V-AC) and the amplifier valve (V-AM) function together as a hydraulic amplifier increasing the quantity and pressure of liquid flow.

The acceleration valve body acts as a freemoving valve. As the areas of chambers 3 and 4 at opposite ends of the acceleration valve are equal, the pressures PR and PRI are equal. It is apparent then that movement of this valve is controlled by the flow of liquid into and out of the chambers. Chamber 3 is directly connected to the bottom chamber of the amplifier valve (chamber 2). Unless the amplifier valve operates to increase or decrease the amount of liquid in chamber 3 of the acceleration valve, the position of the acceleration valve remains unchanged.

Movement of V-AC causes flow of PR liquid into or out of chamber 4 of the acceleration valve. This flow is augmented (amplified) by the action of the acceleration valve tube.

The acceleration valve tube is similar to the amplifier valve tube in design and operation.

As the amplifier valve moves upward drawing PRI liquid from chamber 3 of the acceleration valve into its own chamber 2, the acceleration valve body moves to the left, increasing the volume of chamber 4. This movement connects the PR system to PX through the slot in the V-AC tube and the port in the valve body, while the port in the PI system is closed off. As a result, an augmented flow of liquid in the PR system takes place.

When the amplifier valve moves down, the reverse action takes place, forcing the acceleration valve body to the right into chamber 4. This opens PI to the PR system and augments PR flow.

PR pressure will remain practically the same throughout all the above operations, being immediately balanced by the action of the main valve (V-M).

MAIN VALVE.—The main valve (V-M) is hydraulically controlled by the acceleration valve and the response piston (P-R). It hydraulically positions the main (stroking) piston, which mechanically positions the A-end tilting box.

Chamber 4 at the acceleration valve is connected to chamber 5 at the main valve. Chamber 6, located at the opposite end of V-M, is connected to PI (maintained at a constant pressure). The main valve will remain stationary if there is no movement of the amplifier or acceleration valves. Since PI in chamber 6 is constant, it is evident that the movement and position of the main valve is controlled by liquid flow in chamber 5. When liquid flows out of chamber 5, the main valve moves to the right. Chamber 7 becomes connected to PX. A flow of liquid into chamber 5 moves V-M to the left, connecting chamber 7 to HPC. Thus a pressure, designated intermediate high pressure (IHP), is generated in chamber 7. With the main valve at neutral, both the ports of HPC and PX are open by equal and very slight amounts. With HPC being 1,000 psi (train) and PX being zero, the pressure formed in chamber 7 will be 500 psi, assuming the main valve is at neutral.

If the main valve is moved to the right (by liquid flowing out of chamber 5), IHP will become less than 500 psi, as it is opened to PX, and HPC is closed off. Likewise, if the main valve is moved so that the port supplying HPC to chamber 7 is opened a greater amount, the port connecting PX is more nearly closed. In this case, IHP will become greater than 500 psi.

IHP, originated and controlled at the main valve, is connected by piping to a chamber at one side of the main piston. The other side of the main piston is connected to HPC, which is held constant at 1,000 psi. Since the area upon which HPC acts is exactly one-half the area upon which

ANSWERS TO QUESTIONS Q1 THROUGH Q3.

A1. Automatic, local, hand, and manual.

A2. 360°.

A3. Automatically and manually.

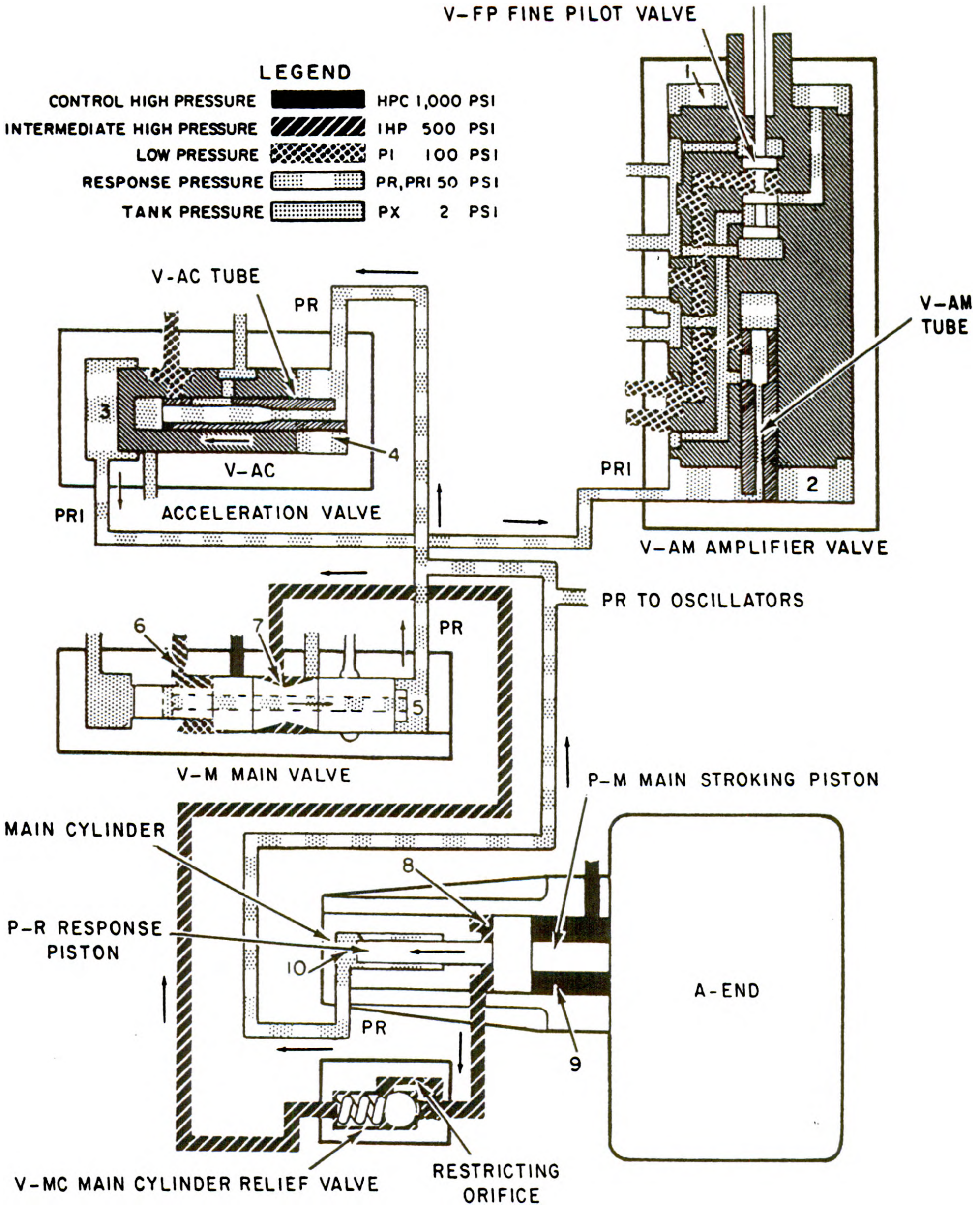


Figure 6-5.—Regulator hydraulic control circuit.

IHP acts, the main piston will be held fixed in one position when IHP is one-half of HPC. Whenever IHP varies from its normal value of one-half HPC, because of motion of the main valve, the main piston will move. Movement of the main piston moves the A-end tilting box and the guns.

For simplicity of explanation, we have purposely left the connection of PR to the response piston out of the picture until now. Because of the design of the main piston and response piston, you may consider that PR will not affect the balance obtained by HPC and IHP at the main piston. As soon as the main piston moves (the response piston moving with it), the change of volume in the PR line will be compensated for by the oil displaced by the response piston.

The reason for establishing an oscillatory effect in the hydraulic control system was explained in the last chapter. This effect is introduced by the sump pump and oscillator into the PR system. The motion is imparted to all of the valves described so far.

SELECTOR VALVE.—This important valve is used as a hydraulic switch to make various hydraulic connections throughout the system as necessary for the different types of control. It is mechanically positioned by means of the control selector lever on the handwheel drive assembly.

The following pressures are involved in the action of the selector valve and are referenced throughout this section:

1. Pump high pressure (HPP)—train psi 1,000, elevation psi 500
2. Control high pressure (HPC)—train psi 1,000, elevation psi 500
3. Intermediate high pressure (IHP)—in neutral 1/2 of HPC
4. Low pressure (PI)—psi 100
5. Tank pressure (PX)—approximately psi 2

Automatic Position.—In the AUTOMATIC control position (figure 6-6, view A), HPC is originated at the selector valve by being connected to pump high pressure (HPP). The hand control clutch operating piston (P-HCC) in the A-end control unit is connected to tank pressure PX and thus disconnects the handwheels from the A-end control unit. Also in this position the selector valve delivers HPC to the synchronizing control valve, placing the synchronizing control device in a position to respond to changes in the amplifier valve.

Local Position.—In figure 6-6, view B, the selector valve has been shifted to the right by placing the control selector lever in LOCAL. HPP remains connected to HPC, keeping the A-end tilt under control of the regulator system. P-HCC in the A-end control unit is connected to PX, keeping that unit still disconnected. The two ends of the fine pilot valve are connected to tank pressure, preventing the coarse pilot valve (V-CP) from building up pressure PI at V-FP in a way to cause it to operate. The synchronizing control device is made inactive by connecting it to PX.

When the control selector lever is moved to LOCAL, the handwheel drive is connected to the fine pilot valve. Rotation of the handwheels, therefore, controls the regulator and the power drive through the fine pilot valve.

Hand Position.—In hand operation, the selector valve is positioned as shown in figure 6-6, view C. The control high pressure and the intermediate high pressure are connected to tank pressure. The regulator, therefore, no longer exerts control over the main piston and the power drive. With pressure removed, the main piston offers no resistance to movement of the A-end tilting box. The selector valve now delivers HPP to the hand control clutch enabling the handwheels to control the power drive through the A-end control unit.

Manual Position.—In the MANUAL position (figure 6-6, view D), the selector valve is moved still further right, and all pressures controlled by the valve are connected to tank pressure. This action renders not only regulator control but also the entire hydraulic power drive inoperative. At the same time, movement of the control selector lever engages the manual drive clutch. The guns now can be operated only through mechanical means by rotation of the handwheels.

Q4. *What is the purpose of the relief cam assemblies?*

Q5. *How is the amplifier valve (V-FP) positioned?*

Q6. *When is the fine pilot valve connected to the handwheel drive?*

Methods Of Operation

Before commencing the study of methods of control, we will restate two facts about automatic and local control:

1. The function of the hydraulic control system is to bring about controlled motion of the main piston, and thereby controlled motion of the guns in accordance with some signal.

2. At all times the main valve will be positioned by the change in PR volume. (This is done in such a way as to allow the change in PR

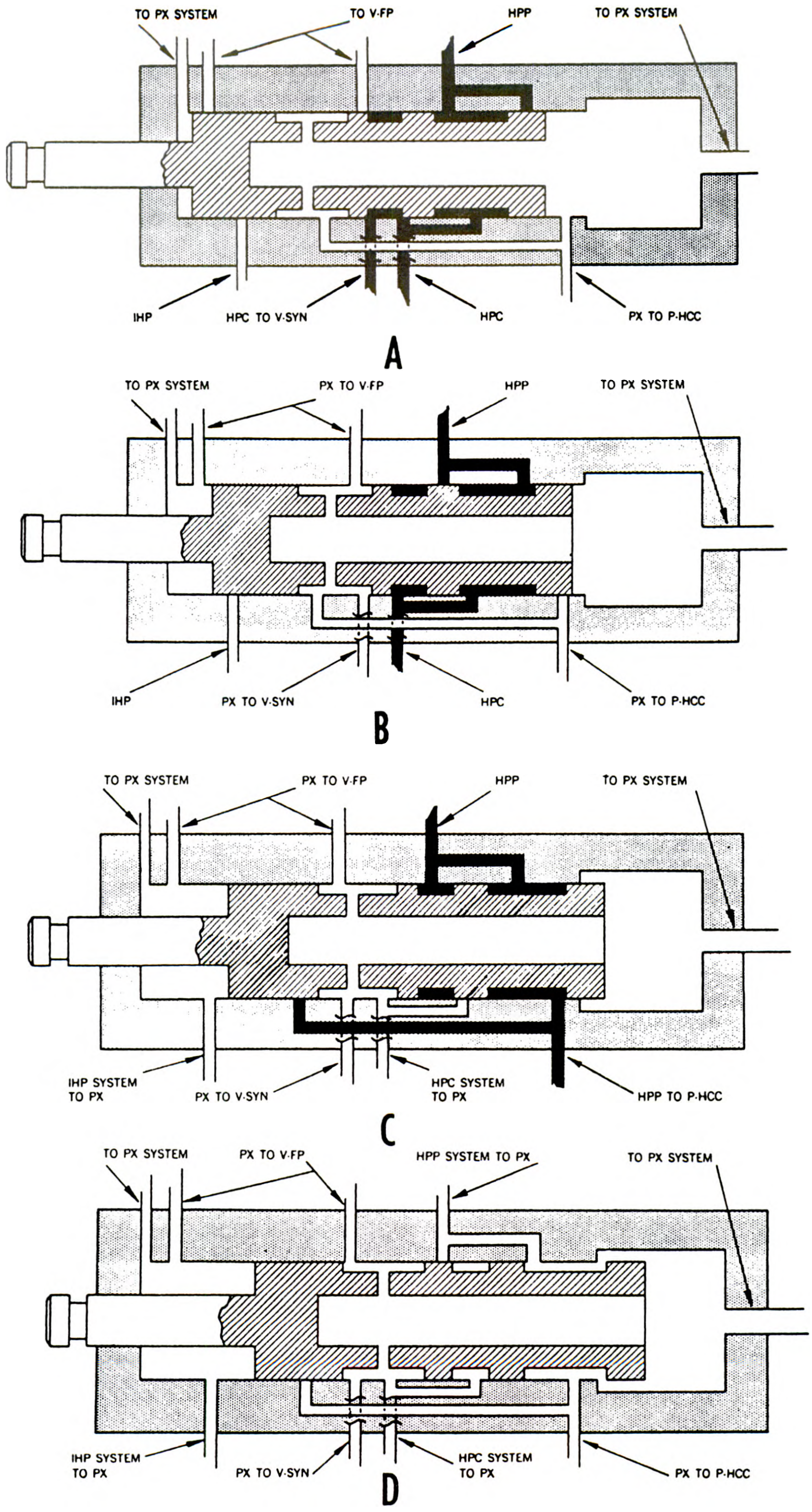


Figure 6-6.—Selector valve: A. Automatic position; B. Local position; C. Hand position; D. Manual position.

volume to be taken care of by the movement of the response piston.)

AUTOMATIC CONTROL.—Placing the control selector lever in the AUTOMATIC position removes the handwheels from the control picture.

The incoming electrical gun order signals received by the control TRs produce relatively weak rotary motions. Through the action of the fork attached to the fine control TR rotor and the differential cam assembly, the cam follower is caused to move up or down. Attached to the cam follower is the fine pilot valve.

Let's return to figure 6-5, and assume that the incoming signal is such that the fine pilot valve is drawn upward. Chamber 1 at the top of the amplifier valve is opened to PX (tank pressure), allowing the amplifier valve to move upward. Liquid is drawn from the PRI system into chamber 2 of the amplifier valve. This flow is aided by opening chamber 2 to PX through the slot in the amplifier tube.

As V-AM moves upward, drawing PRI liquid from chamber 3 of the acceleration valve into its own chamber 2, the acceleration valve body moves to the left, increasing the volume in chamber 4. As the acceleration valve body moves to the left, PR is connected to PX through the slot in the acceleration valve tube, and the flow of liquid in the PR system is augmented.

As the acceleration valve body moves to the left, liquid is drawn into its chamber 4 from chamber 5 of the main valve. The main valve moves right, porting IHP at chamber 7 to PX. Reducing the pressure of IHP causes the main piston to move to the left in the main cylinder. This moves the tilting box in the direction to produce the required amount of right train. If a signal was introduced for left train, all of the actions described above would occur but in opposite directions.

Mechanical response acts as soon as rotation of the B-end starts. When the guns have caught up to the signal, mechanical response geared to the differential cam causes return of the fine pilot valve to neutral.

LOCAL CONTROL.—Operation in local control is similar in many respects to automatic control. In both types of control, the hydraulic control system governs the operation of the mount.

In local control, however, the fine pilot valve is controlled by rotation of the handwheels, and not by the electric signal received by the control TRs. The coarse pilot valve is disconnected from the system, and the synchronizing control device is hydraulically locked in its neutral position.

When the control selector lever is shifted to LOCAL, a notch in a cam is positioned opposite a follower on the local control pivoted arm. The pivoted arm is moved as the follower enters the notch in the cam by spring action. This causes the roller to bear on a friction disc, mounted on the fork assembly, which rotates in and with the differential cam. Rotation of the handwheels rotates the roller in contact with the friction disc and, thereby, controls the motion of the fine pilot valve V-FP.

From this point, the hydraulic control system functions as in automatic control.

In all types of control except local, the friction roller is held out of contact with the friction disc by the action of the notched cam and its follower.

MANUAL CONTROL.—In manual control, the handwheels are connected directly to the training worm or elevating pinion by gears and shafts. Because of the load, the speed selector lever must be in the LOW position.

ANSWERS TO QUESTIONS Q4 THROUGH Q6.

A4. To permit the fine and coarse TRs to continue to follow the gun order signal when the pilot valves have reached their limit of travel.

A5. Mechanically by the output of the differential cam.

A6. When the selector lever is moved to local.

All hydraulic control pressures are opened to exhaust by action of the selector valve; therefore, the spring-loaded brake valves act to position the A-end tilting box to its neutral position.

The hydraulic block between the B-end (rotated by response) and the A-end is eliminated by the action of the antioverhaul mechanism. This device was explained in the preceding chapter.

HAND CONTROL.—In hand control, motion of the handwheels positions the A-end tilting box through the A-end control unit. The hydraulic control mechanism in the indicator-regulator is made inoperative by the action of the selector valve when the selector lever is in the HAND position. The selector valve also connects both sides of the main piston to exhaust, thus eliminating resistance to movements of the A-end tilting box. At the same time, the selector valve ports high pressure oil to the hand control clutch piston at the A-end control unit. A schematic of the A-end control unit is shown in figure 6-7. For the present, disregard the limit-stop mechanism shown in the same illustration.

Notice that the control mechanism is a sort of differential arrangement with two inputs—handwheel motion and B-end response. The output, which represents the difference between the two, positions the A-end tilting box. Note that the response gear (2) has a spliced bore to fit the spliced end of the screw control shaft (13). While the screw control shaft turns with gear (2), it is free to move laterally through it.

At its opposite end, the screw control shaft is a screw with a large lead. It is fitted through the signal gear (1).

Rotation of gear (1) (while gear [2] is stationary) causes the screw control shaft to move laterally through the threaded bore of gear (1) and the spliced bore of gear (2). Rotation of gear (2) will also rotate the screw control shaft and cause it to move laterally.

Assume now that the guns are at rest and a signal is introduced to the A-end control unit by rotation of the handwheels. This rotation is

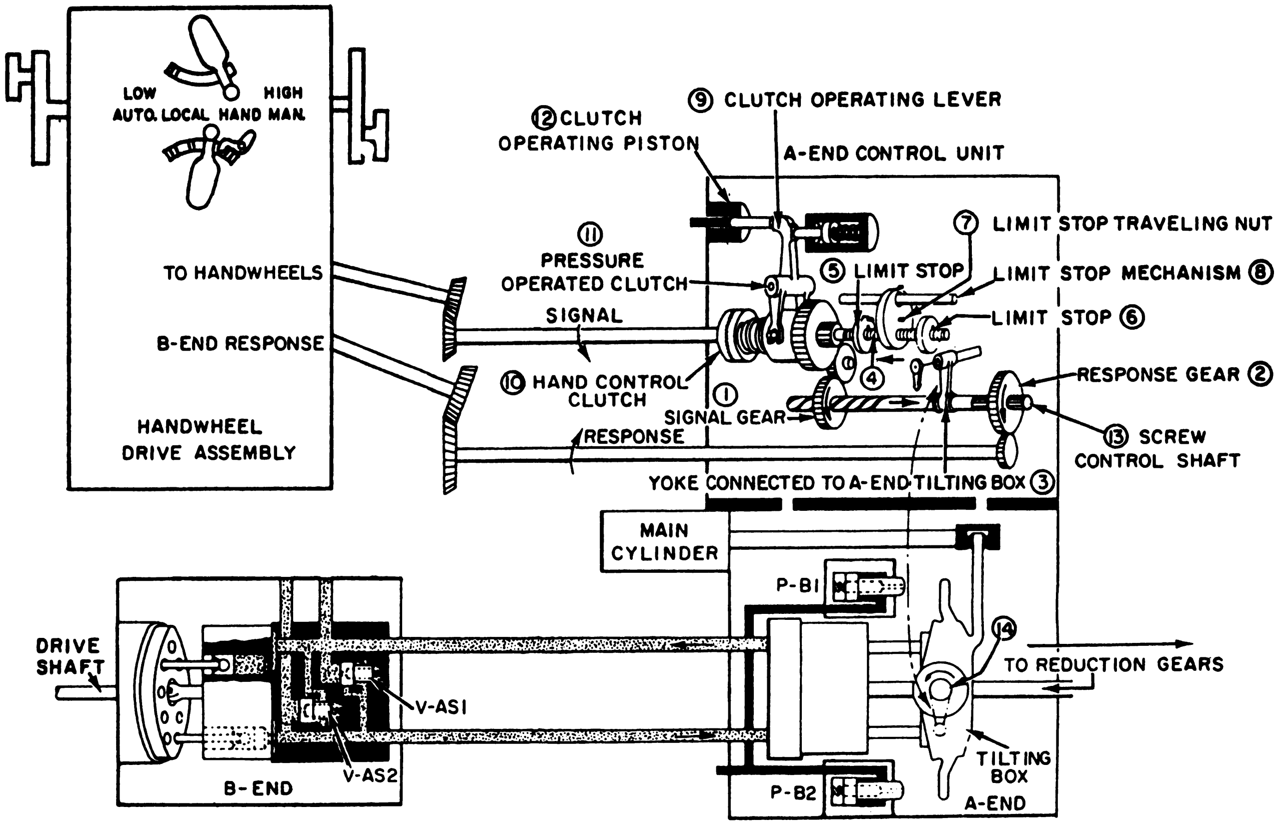


Figure 6-7.—A-end control unit.

transmitted to gear (1) through the clutch (11), which is held engaged by oil pressure from the selector valve. Rotation of gear (1) cannot by itself rotate the screw control shaft which is held by gear (2). Because of the lead of the screw, rotation of gear (1) results in lateral movement of the screw control shaft (13) through it and, thus, introduces an angle of tilt to the A-end tilting box. This will result in movement of the mount.

As soon as the mount moves, B-end response begins to rotate the response gear (2) in the same direction as the signal gear (1). As long as gear (1) is rotating faster than gear (2), the screw control shaft (13) will continue to move the A-end tilting box.

When the angle of tilt is such that the mount is moving at a speed corresponding to the speed of rotation of the handwheels, the speed of gears (1) and (2) will be the same. Under these circumstances, there will be no further lateral movement of the shaft. When the speed of the response gear (2) becomes greater than that of the signal gear (1), the screw control shaft (13) begins to return the A-end tilting box to neutral, slowing the speed of the B-end.

Limit-Stop Operation

The limit-stop mechanism (8) is located in, and acts in conjunction with, the A-end control unit. Its purpose is to stop the guns within predetermined limits of train before the positive stops are reached. Its operation is the same in all methods of power control.

The limit-stop mechanism consists of a nut traveling on a threaded shaft (4) between two adjustable stops (5 and 6).

The threaded shaft is geared through an idler with gear 1 and rotates with it. When the traveling nut is driven into one of the limit stops, it jams and prevents rotation of gear 1.

As the handwheeels are rotated in hand control, the traveling nut moves toward one or the other of the stops. As the guns reach the predetermined limit of train, the traveling nut will contact the stop. Further rotation of the handwheels causes the spring relief on the clutch to slip. As before, gear 1 is prevented from rotation by the limit-stop mechanism.

Since the guns are in motion at the instant the limit stop acts, the A-end tilting box has a definite angel of tilt. Mechanical response is still being applied and is rotating gear 2 and the screw control shaft. As gear 1 is prevented from rotating, the screw control shaft is moved through it laterally. This movement of the shaft returns the tilting box to neutral and the guns to rest.

In both local and automatic control, the indicator-regulator controls the A-end tilting box. The hand control clutch is disengaged. B-end response, however, is still being applied to gear 2. As gear 2 and the screw control shaft rotate, gear 1 (with little appreciable resistance acting on it) will rotate and drive the traveling nut toward one of the limit stops. As the stop is reached, gear 1 is prevented from rotating further. The screw control shaft, which is being rotated by gear 2, is now forced to move through gear 1. This action will result in returning the tilting box to neutral.

In both local and automatic control, the main piston (connected to the A-end tilting box) will be moved by the limit-stop mechanism, regardless of the dictates of the hydraulic control system. Chambers of the main piston are relieved by relief valve V-IHP located in the regulator control valve block.

Q7. In automatic control, what causes the main piston to move to the left in the main cylinder?

Q8. In local control, what controls the fine pilot valve?

Q9. Where is the limit-stop mechanism located?

Q10. What is the purpose of the limit-stop mechanism?

Coarse Control

In the discussion of automatic control, the gun order signal was considered as coming into a single synchro receiver (the fine control TR). This synchro, working in conjunction with the differential cam assembly, controls the position of the fine pilot valve initiating regulator action to bring the mount into synchronization with gun order.

Remember, however, that the fine control TR is 36 speed and will synchronize at any multiple of 10° from the gun order signal. This could easily be the case when the gun is shifted to automatic if there is a large difference between gun order signal and gun position.

To prevent the mount from synchronizing 10° from the signal, another system called the coarse control system (fig. 6-8) is incorporated into the regulator. Essentially the system is composed of a 1-speed TR and a coarse pilot valve.

The coarse control TR receives the same gun order signal as the fine control TR, but rotates at only 1 speed in train (2 speeds in elevation). Rotation of its rotor positions the coarse pilot valve, which is fastened to its output shaft. Mechanical response from the B-end is geared to the stator of the coarse control TR and will rotate it an equal amount, but in the opposite direction. The rotating stator carries the rotor with it, so that response actuates the return of the rotor and the coarse pilot valve to its original position.

As shown in figure 6-8, the spaces above and below the fine pilot valve are vented to cavities in the sides of the amplifier piston and from there to the coarse pilot valve through two lines. Narrow grooves in the amplifier piston permit a small flow of oil from the PI into this system. As long as the coarse pilot valve is at neutral, the chambers at either end of the fine pilot valve are connected to drain. This allows the fine pilot valve free movement for control of the mount.

Assume that a signal is received which moves the fine pilot valve upward. When the error between gun order and gun response is approximately 2°, the fine pilot valve is displaced to the limits of its travel.

When the error reaches 3.8°, the coarse pilot valve will shift to the left, blocking PA to exhaust. With PA blocked to exhaust, PA would become the same pressure as PI and the fine pilot valve would be forced upward, in turn forcing the amplifier to move up to its extreme position. As a result, the guns will drive at maximum speed

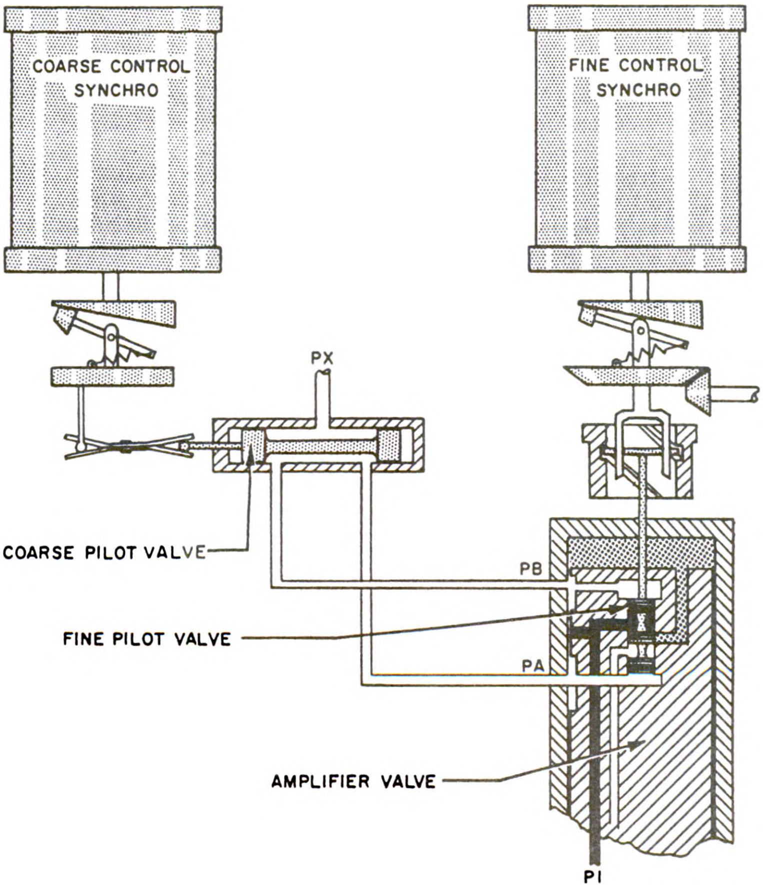


Figure 6-8.—Coarse control system.

toward synchronization. As the error between gun order and gun position drops below 3.8°, the coarse pilot valve shifts to reopen PA to PX and the fine pilot valve resumes control.

Overtravel Due to Change in Signal

As there is an inertia lag inherent in the design of the control equipment, the control valves go through a series of diminishing oscillating or hunting movements between the beginning and end of their response to a signal.

Mechanical response acts as soon as rotation of the B-end starts. When the guns have caught up with the signal, therefore, mechanical response has returned the fine pilot valve to neutral. At this point, however, gun velocity still exceeds the signal velocity, and the signal is overrun. Mechanical response then displaces the fine pilot valve below neutral causing control valves V-AM, V-AC, and V-M to be positioned in the opposite direction from their original displacements. The main piston, response piston, and the A-end tilting box return part way toward neutral decelerating the guns. This signal now catches up with gun position; but, as the guns are decelerating, the signal overruns and again leads the guns. This slowing of mechanical response permits the signal to again raise the fine pilot valve above neutral, but for a shorter distance than originally. Thus the ensuing repetition of the original cycle of valve movements is on a smaller scale because the guns have become nearly synchronized with the signal as a result of the original action.

Identical cycles of valve movements continue with diminishing amplitude until gun position, velocity, and acceleration are synchronized with the same values of the signal. With your equipment in good operating condition, the maximum number of overtravel cycles will be three.

Synchronizing Control Device Operation

This device functions only in automatic control. Its purpose is to bring the guns into synchronization with gun order rapidly and smoothly when the existing error exceeds 1.5°. Errors of this magnitude are usually encountered when the mount is shifted to automatic control. After gun order and gun position agree, the error should not again become great enough for further action of the synchronizing control device.

This device will operate regardless of whether or not the coarse pilot valve has taken control of the fine pilot piston.

The synchronizing control device discussed here is used only with the Ford power drive found on twin 5"/38 mounts. For this reason, we will discuss only its function, rather than details of construction and operation.

The synchronizing control device gearing will operate to rotate the fine and coarse control synchro stators in such a way as to cause their pilot valves to move toward neutral.

The first output of the synchronizing control device furnishes an apparent response which will cause the fine pilot valve to take control of the equipment when the error is reduced to about one-half of its original value.

The synchronizing device then reverses its rotation so that its second phase produces an apparent signal. The regulator follows this apparent signal in fine control.

As a result of the two outputs of the synchronizing control device, the period of high acceleration is shortened, gun overtravel is reduced, and the guns and signal are synchronized smoothly and quickly.

ANSWERS TO QUESTIONS Q7 THROUGH Q10.

A7. Reducing the pressure of IHP.

A8. Rotation of the handwheels.

A9. In the A-end control unit.

A10. To stop the gun before the positive stops are reached.

Synchro Power Failure Device Operation

The synchro power failure device (fig. 6-9) operates to bring the mount to a standstill in the event of loss of synchro supply. The three main components of this device are (1) a solenoid (energized by the synchro supply circuit), (2) a friction brake, and (3) the synchro power failure valve. The valve and friction brake are attached to a vertical, axially-movable shaft. The spring-loaded shaft is normally held in its down position by the action of the solenoid and lock arm when the equipment is in automatic control. In other types of control, the shaft is held down (and inoperative) by action of the cam on a roller of the latch arm.

When synchro supply fails, the solenoid acts to trigger the release of the spring-loaded shaft. The cork-faced brake surface then comes into contact with the local control friction disc, arresting further rotation of the fine synchro fork.

To prevent the coarse pilot valve, now uncontrollable, from blocking either PA or PB and thus keeping the fine pilot valve fully displaced, the synchro power failure valve pulls up, closing PA and PB to PX. The pressures at both ends of the fine pilot valve become equal through the connecting ports of PI. Mechanical response, rotating the differential cam, returns the fine pilot valve to neutral.

So far we have discussed the control equipment used with the 5″/38 gun system. In the next section of this chapter, we will explain the hydraulic control equipment used with the 5″/54 gun system.

Q11. What prevents the gun from synchronizing 10° from the signal?

Q12. What is the maximum number of overtravel cycles you should experience if your equipment is in good operating condition?

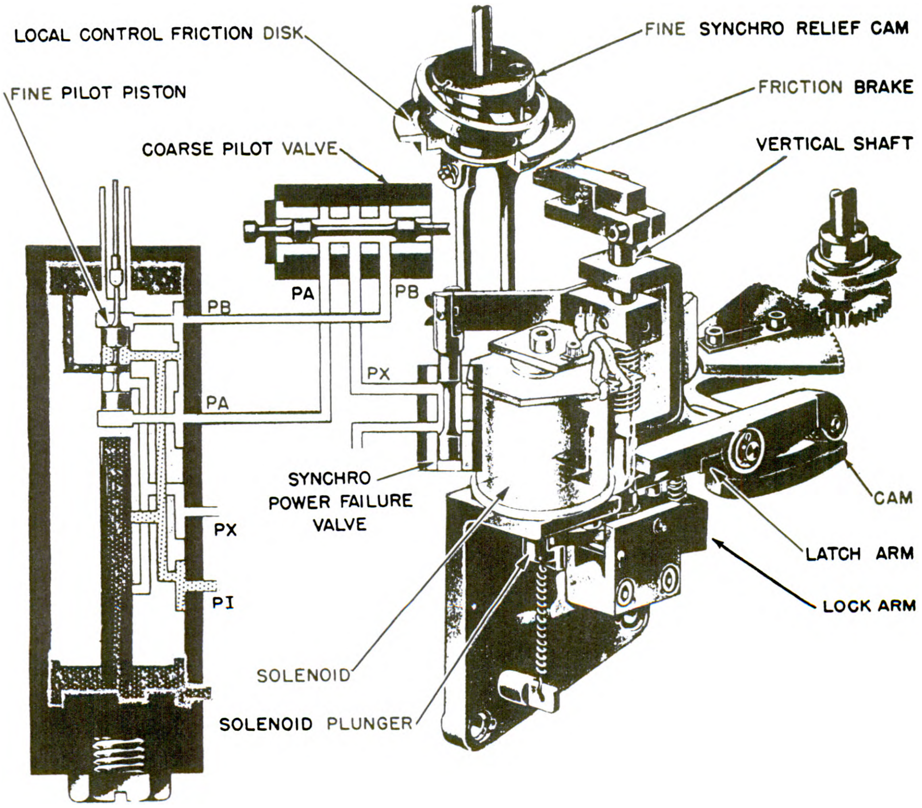


Figure 6-9.—Synchro power failure device.

Q13. What is the purpose of the synchro power failure device?

5"/54 MK 42 MODS 9 AND 10 GUN MOUNT CONTROL EQUIPMENT

The 5"/54 Mk 42 gun mount was developed as an AA gun to be used against high speed jet aircraft. It has proved to be a reliable and efficient weapon system.

To obtain better control and faster response to gun order signals, a new type of receiver-regulator was developed for the 5"/54 gun system. It is a major element of the hydraulic control system and is similar in purpose to the indicator-regulator you studied on 5"/38 control equipment, but it differs considerably in component details. These differences will be readily apparent to you as we go along with the study of the receiver-regulator and its associated equipment for control of the 5"/54 hydraulic power drive.

METHODS OF CONTROL

The control equipment for these gun mounts may be operated from any of the following sources:

1. REMOTE: Signals originating at the remote source in a fire control system (FCS) which provide the order signals for mount movement.

2. LOCAL: Local order signals for each power drive are generated at the EP2 panel by synchro control transmitters (CXs). Manually operated controls (handwheels) on the front of the EP2 panel drive the rotors of the CXs and the indicating dials. Each handwheel is geared to two CXs (1X and 36X) which transmit position signals to their respective power drives in the same way as the remote signals do.

3. TEST: When the mount is in test control, an external (dummy) director supplies order signals to either the train or the elevation power drives. Under test conditions, an external director can be connected into the circuitry through connections in the test plate at the rear of the EP2 panel by the gun crew.

4. OMC: The one-man control (OMC) unit generates positioning signals from a station in the gunhouse. Direction and velocity information from the OMC is applied to the servo amplifier as an operator manipulates the handgrips to position the mount.

RECEIVER-REGULATOR

The receiver-regulators for train and elevation units are similar except that the elevation receiver-regulator receives a train response from the train pinion. Only the train receiver-regulator will be discussed in detail.

The train receiver-regulator, in conjunction with the servo amplifier, controls the train CAB unit in response to train order signals. Receiver-regulator components receive remote train order signals from FCS, local train orders from the local director (EP2 panel) or external director, or OMC train orders from the OMC unit and mechanical responses from the train CAB unit.

Error and velocity signals, developed by receiver-regulator components, are processed by the servo amplifier. The amplifier produces a control signal to operate the electrohydraulic servo valve inside the regulator. The servo valve controls the CAB unit by porting pressurized fluid to the stroking pistons which, in turn, position the A-end tilt plate. The components of receiver-regulators are (1) the cover, (2) the base plate, (3) the nonpointing zone and synchro gear assembly, (4) the nonpointing zone valve block, (5) the servo valve, (6) the dither transformer, (7) the A-end

ANSWERS TO QUESTIONS Q11 AND Q12.

A11. Coarse control system.

A12. Three.

response linkage, and (8) the B-end response gear assembly.

Regulator Cover

The regulator cover is a one-piece cover with a watertight, airtight seal which protects regulator components. A window permits observation of indicating dials mounted on the synchro assembly. An air valve and an air inlet in the top of the cover permits the air within the cover to be replaced with inert gas.

Base Plate

The base plate of the receiver-regulators serves as a chassis for supporting the various mechanical and electrical components to the receiver-regulator. The base plate has drilled passages for porting hydraulic fluid to the nonpointing zone valve block, the electrohydraulic servo valve, and the A-end stroking pistons. Electrical connections between the receiver-regulator and servo amplifier are made through three connectors mounted on the base plate. The A-end stroking piston arm and the B-end response gear assembly are mounted on the underside of the base plate.

Nonpointing Zone and Synchro Gear Assembly

The nonpointing zone and synchro gear assembly (train) (fig. 6-10) contains (1) synchros (not visible in illustration), (2) a position-plus-lead switch and cam stack, (3) limit stops assembly, (4) indicator dials, (5) a position switch and cam stack, (6) a speed reducer, and (7) a differential speed reducer. The synchros receive order signals from the fire control system and process them for use in positioning the mount. The nonpointing zones prevent the gun from damaging the ship's structure. The position and position-plus-lead cam stacks and the limit stops aid in bringing the mount to a gradual stop. Indicating dials show the position of the mount in train and elevation. The position of the switch cam stack provides mount position information for use by the nonpointing zone system. The differential speed reducer transmits the B-end responses to the synchros, the speed reducer, the indicator dials, and the position switch cam stack.

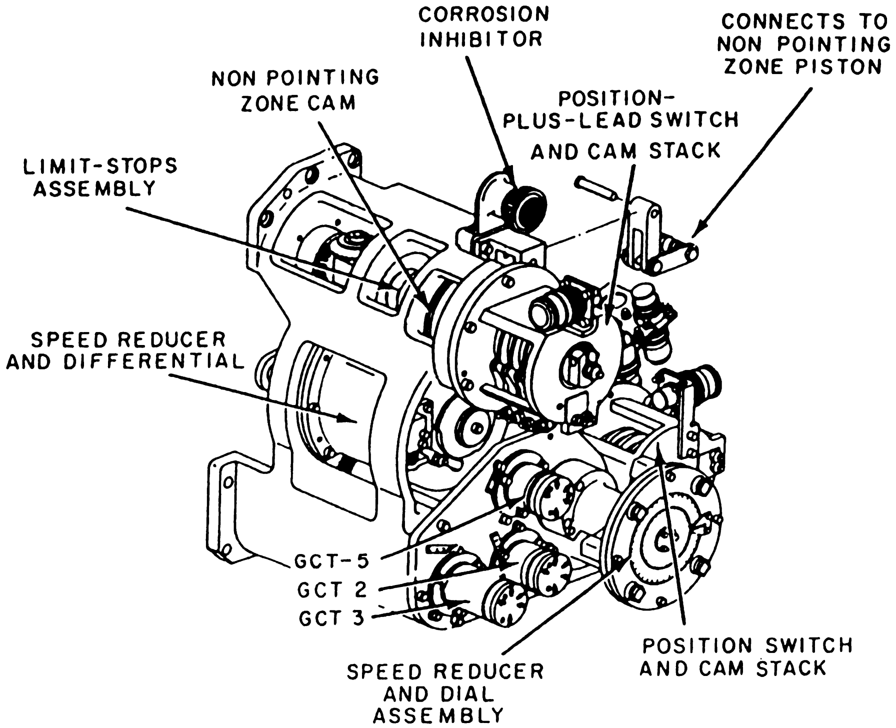

CORROSION INHIBITOR
CONNECTS TO NON POINTING ZONE PISTON
NON POINTING ZONE CAM
POSITION-PLUS-LEAD SWITCH AND CAM STACK
LIMIT-STOPS ASSEMBLY
SPEED REDUCER AND DIFFERENTIAL
GCT-5
GCT 2
GCT 3
POSITION SWITCH AND CAM STACK
SPEED REDUCER AND DIAL ASSEMBLY

Figure 6-10.—Nonpointing zone and synchro gear assembly (train).

Nonpointing Zone Valve Block

The nonpointing zone valve block (train) (fig. 6-11) includes a nonpointing zone piston, solenoid valves, solenoids, an override device, and an electrohydraulic servo valve. The override device extends from the inboard side of the valve block. The limit-stop lever is connected to the override device, and the override device is connected to the electrohydraulic servo valve.

Servo Valve

The servo valve is mounted to the automatic nonpointing zone valve block. Four parts (a pressure part, a return part, and two control parts) in the bottom of the servo valve body connect to openings in the side of the automatic nonpointing zone valve block.

The electrohydraulic servo valve (BCT1) controls the porting of pressurized fluid to the A-end stroking pistons of the train CAB unit. In, normal operation the servo valve converts electrical signals from the electronic servo control amplifier into controlled hydraulic flow to the hydraulic transmission. In nonpointing zone or limit-stop operation, the servo valve is mechanically controlled by components of the A-end response linkage.

Dither Transformer

The dither transformer (fig. 6-12) is a 60-cycle stepdown type wired into the electrohydraulic servo valve force motor circuit. The transformer dither signal prevents static friction from causing the servo valve to stick by passing alternating current through the servo valve and thus keeping it constantly vibrating. A potentiometer mounted on the top of the dither transformer is adjusted to control the strength of the dither signal.

A-End Response Linkage

A-end response linkage is mounted on the receiver-regulator base plate. It consists of a limit-stop cam, a stroke response potentiometer, a

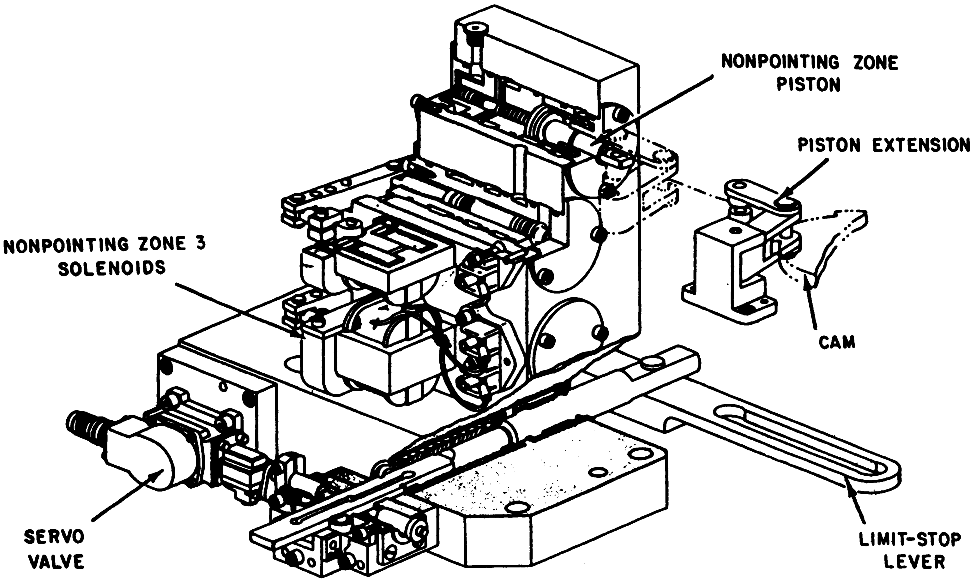


Figure 6-11.—Nonpointing zone valve block (train).

ANSWER TO QUESTION Q13.

A13. To bring the mount to a standstill if synchro power is lost.

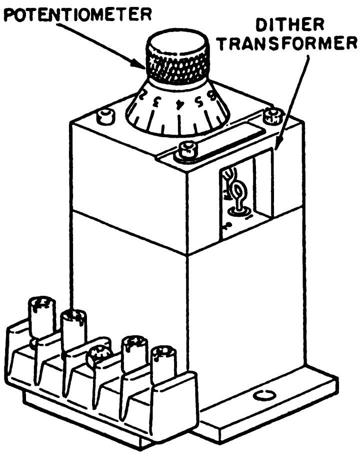


Figure 6-12.—Dither transformer.

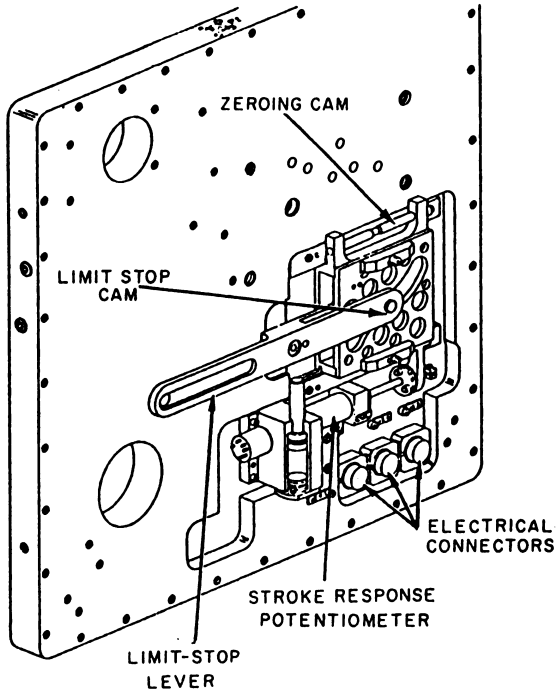


Figure 6-13.—A-end response linkage.

zeroing cam, and a limit-stop lever (fig. 6-13). The A-end response linkage receives the A-end response from the A-end stroking piston arm and transfers the response to the receiver-regulator gear assembly.

The limit-stop cam is connected to the A-end stroking piston arm through a rectangular opening in the base plate. It transfers A-end stroking piston arm movement to the stroke response potentiometer wiper arm, the zeroing cam, and the limit-stop lever.

The stroke response potentiometer receives its power from the servo amplifier and converts the mechanical A-end response to an electrical dc velocity signal.

The zeroing cam, which is connected to the limit-stop cam, deactivates and permits activation of the A-end on-neutral switch.

The limited-stop lever is attached to the camming surface of the limit-stop cam. It transfers A-end response to the receiver-regulator gear assembly.

B-End Response Gear Assembly

The B-end response gear assembly, mounted on the underside of the base plate, transmits B-end output movements from the hydraulic transmission unit to the synchros of the nonpointing zone and synchro gear assembly. The response gear assembly consists of a response housing, shafts, bearings, and gears. The response shaft, which supplies B-end response movements, is equipped with two flexible couplings and a vernier adjustment to aid in alignment procedures.

Q14. The 5"/54 Mk 42 gun mount was developed for what purpose?

Q15. What is the purpose of the nonpointing zone?

ELECTRONIC SERVO CONTROL UNIT

The electronic servo control unit (servo amplifier) is common to the train and elevation systems. It receives, processes, and converts a small ac position error signal from the synchros to a dc signal large enough, and of proper polarity, to activate the electrohydraulic servo valve on the receiver-regulators. The servo amplifier (fig. 6-14) contains front panel controls for adjustment and alignment and 13 plug-in module boards (six for train, six for elevation, and one common power supply module board). The respective module boards for the train and elevation systems are identical and are interchangeable. Each module board has a component designation of PC (printed circuit board) and is designed to perform a different function. The module boards for the train and elevation amplifier are designated as follows:

PC1—Shaping and logic circuit
PC2—Position amplifier
PC3—Compensation circuit
PC4—Compensation amplifier

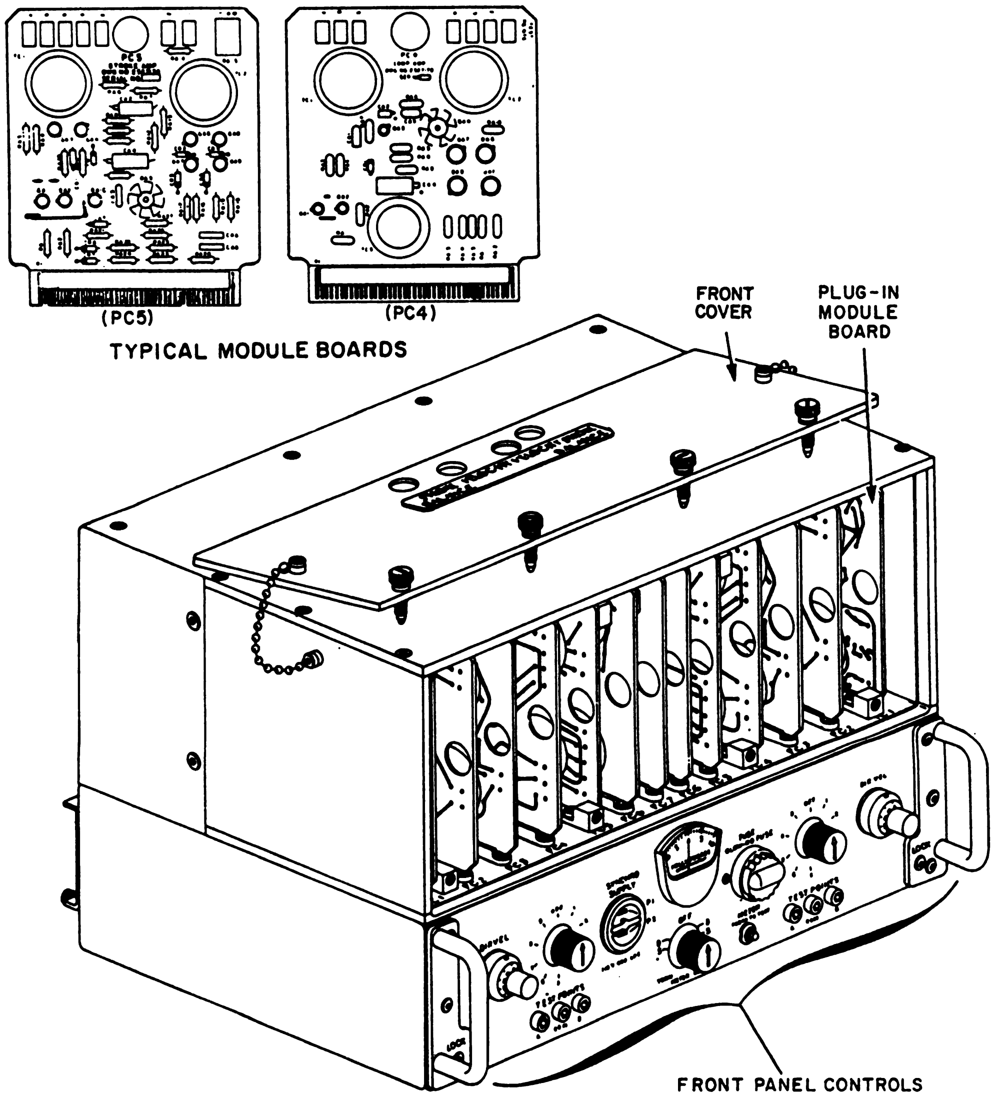


Figure 6-14.—Electronic servo control unit.

ANSWERS TO QUESTIONS Q14 AND Q15.

A14. To defend against high speed jet aircraft.

A15. Prevent gun from damaging the ship's structure.

PC5—Stroke amplifier

PC6—Filter circuit

PC7—Power supplies (common to both systems)

For a functional analysis of the servo amplifier, refer to figure 6-15.

A command signal from the fire control system (FCS) is applied to the 1X and 36X synchros. The output of these synchros is applied to PC1. When the position error signal is less than 2°, the 36X output of PC1 is applied to PC2 through a transistor switch. When the position error is greater than 2°, the 1X output of PC1 is applied to PC2. A switching signal from PC1 is applied to PC3.

Module board PC2 amplifies the 1X or 36X position error signal and adds a dc feedback voltage (B-end velocity signal from a tachometer) to the position error signal. The output of PC2 is applied to PC3. When the position error signal is within 1° of the command signal, the switching signal from PC1 triggers the switching oscillator in PC3 and the switching transistors apply the output of PC3 to PC4, and then to PC6. The purpose of PC4 is to amplify the position error signal when the signal is less than 42 minutes to maintain system accuracy when the error signal is small. When the position error signal is 2° or more, the switching signal from PC1 triggers the switching oscillator in PC3 and the switching transistors apply the output of PC3 directly to PC6. Module board PC6 processes the position error signal, director velocity signal, and A-end velocity response signals to obtain a composite output (stroke servo error) signal.

The director velocity signal comes from a tachometer geared to the controlling director (position order source), which supplies a dc velocity signal to the servo amplifier. The director velocity signal represents the rate of change of the position signal. The tachometer provides one-half volt for each degree per second of position signal change. Positive velocity voltages order right train

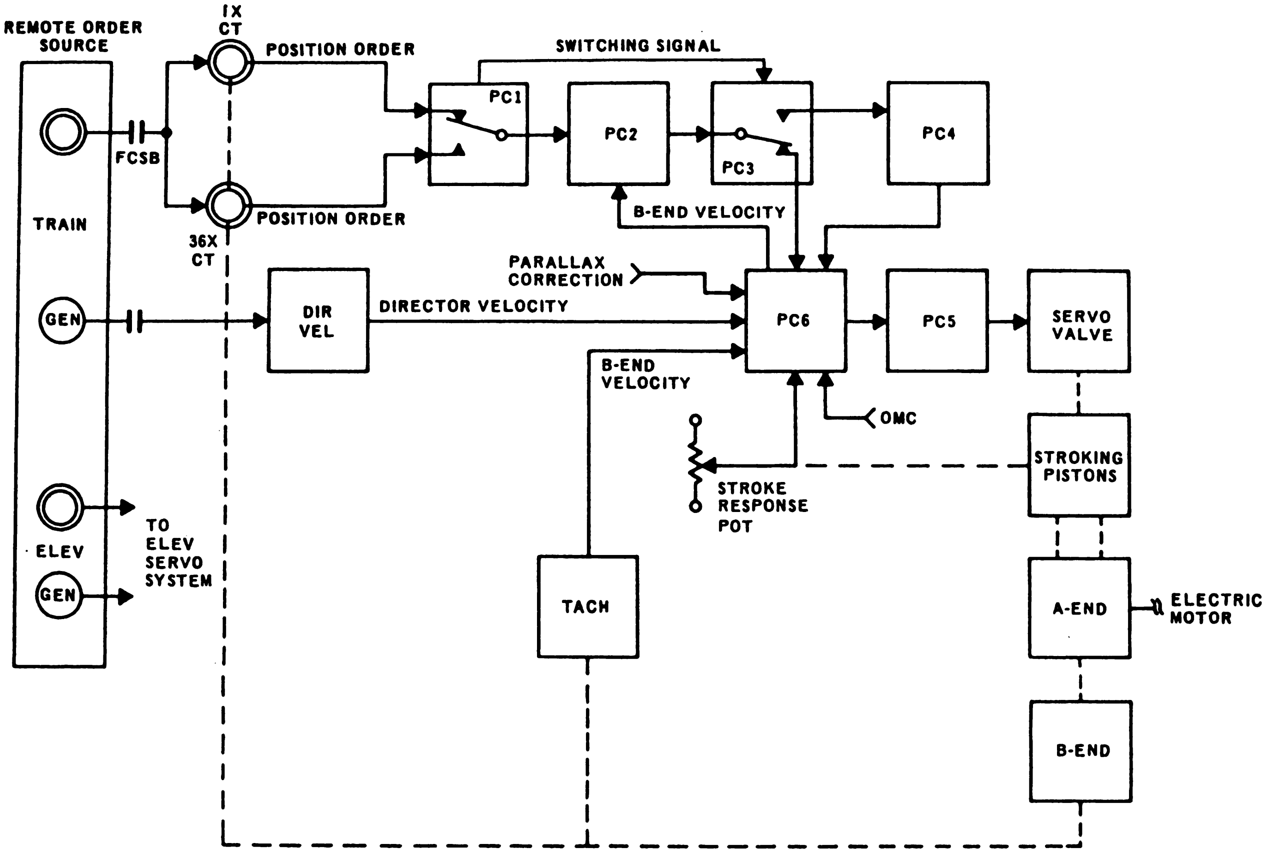


Figure 6-15.—Electronic servo control unit functional diagram.

or elevation, and negative voltages order left train or depression.

Velocity response from the position of the A-end stroking piston automatically adjusts a wiper arm on the stroke response potentiometer (SRP) when the tilt plate moves. The SRP applies a voltage to the servo amplifier that indicates actual mount velocity. The SRP output is negative for increasing orders and positive for decreasing orders.

A velocity and summing circuit, part of module board PC6, acts to match the director velocity signal with the other signals and shapes a response to control the acceleration and deceleration of the servo system. The first summing circuit algebraically adds the position error and the director velocity signal to produce one output signal. This signal is applied to the second summing circuit, which is subtracted from the A-end velocity signal from the SRP. The composite output from the second summing circuit is applied to the stroke amplifier, module board PC5. The output of the second summing circuit has three possible forms: acceleration to the desired velocity that results when the desired velocity is greater than the stroke response; maintenance of the same velocity that results when two signals are equal and their combined output is zero; and deceleration to the desired velocity that results when the stroke response is greater than the desired velocity.

When it is necessary to reverse the direction of system travel, however, the desired velocity is in the opposite direction from the stroke response. The stroke response now adds to the desired velocity. The stroke servo error then orders a greater rate of deceleration. A positive stroke error causes either acceleration for an increasing order or deceleration for a decreasing order.

Module board PC5 modulates, amplifies, and demodulates the dc servo error voltage from PC6. The modulator circuit converts the dc error voltage into either an in-phase or out-of-phase 400-hertz ac signal. The amplifier (three stage) amplifies the modulated 400-hertz signal before it is applied to the demodulator. The demodulator converts the ac input to a dc output to operate the force motor coils of the servo valve.

Module board PC7 (fig. 6-16) provides regulated and unregulated voltage to the circuits in the servo amplifier and the SRP. The common power supply provides synchro reference voltage, bias voltage, train offset voltage, and B-plus voltage to the train and elevation amplifiers. The SRP power supply provides regulated dc voltage to the stroke response potentiometers. To be able to produce a signal in the amplifier ready circuit, a sensing circuit detects the presence of SRP voltage and triggers the oscillator circuit.

FORCE MOTOR COILS

The force motor of the servo valve (fig. 6-17) converts the electrical input supplied by the servo amplifier to a mechanical displacement. The electrical signal applied to the force motor coils

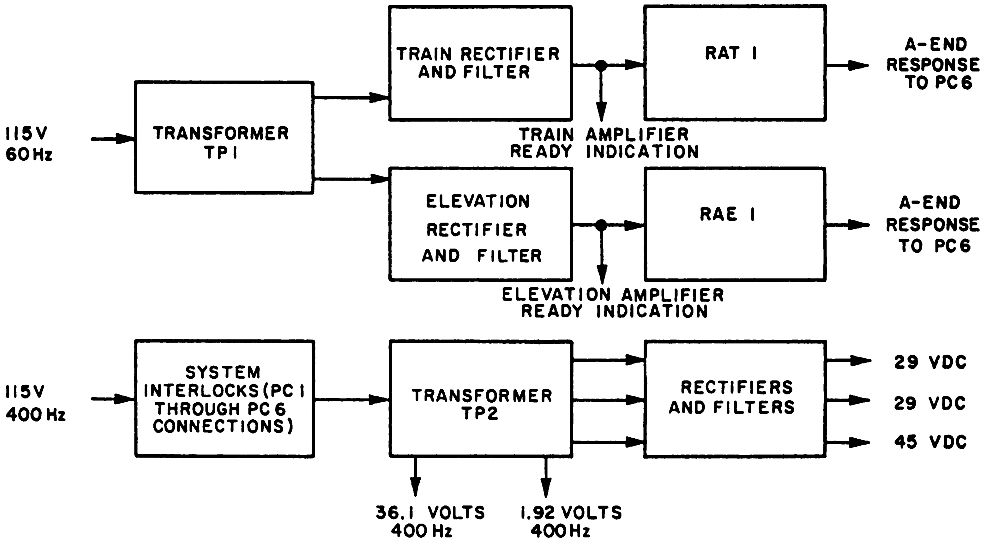


Figure 6-16.—Power supply circuit board, PC-7.

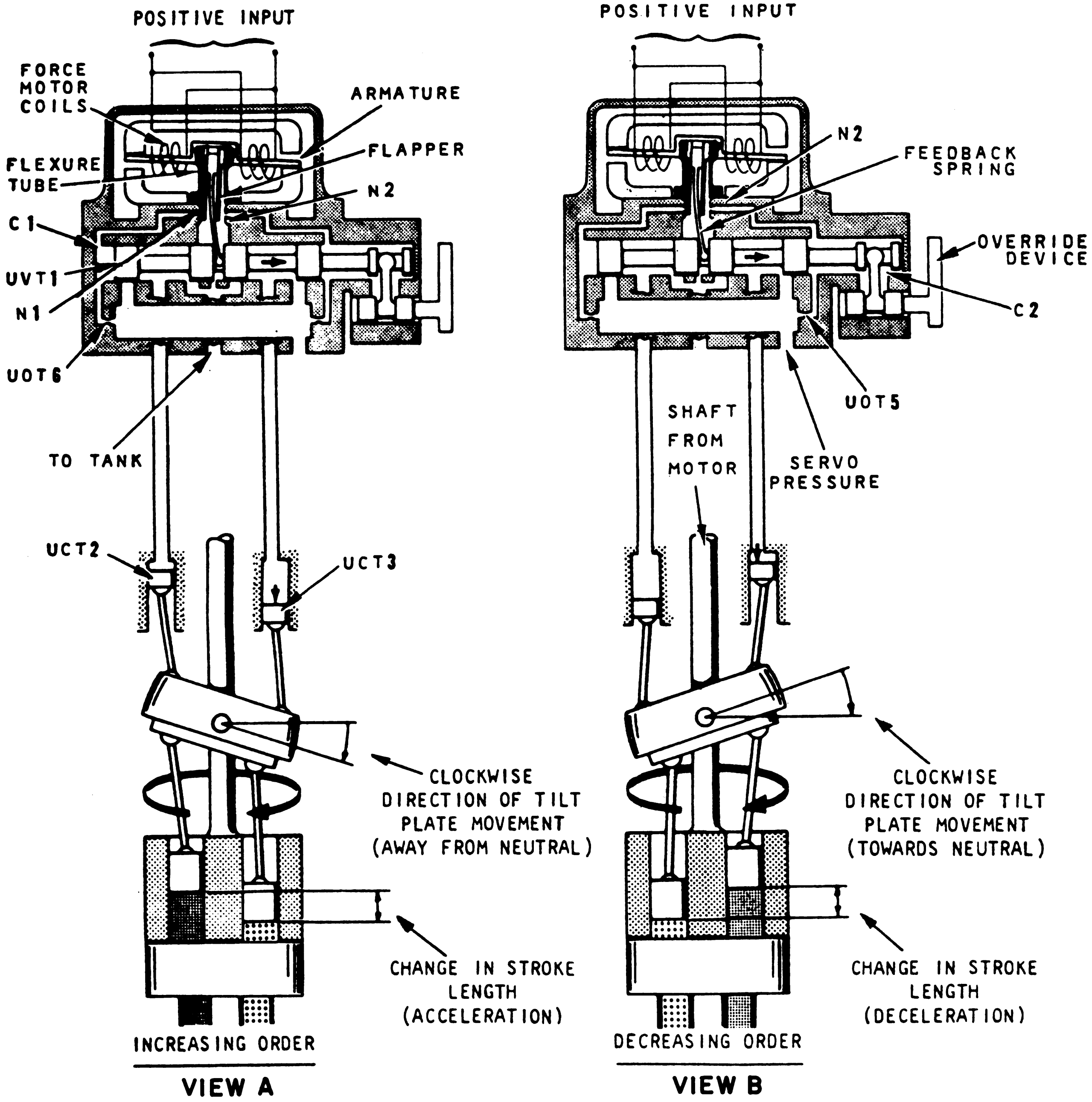


Figure 6-17.—Positive signal in force motor coils.

generates a torque that causes an armature to move and bend on a flexure tube support. A flapper assembly attached to the armature moves with it toward one nozzle (N) and away from the other.

Differential pressures caused by the flapper movements between the nozzles move a plunger (UVT1) of a four-way valve, which regulates hydraulic output to the A-end stroking pistons.

Figure 6-17, view A, illustrates the servo valve positioned for a positive signal. The force motor has shifted the armature and flapper to the position shown in the figure. This shift decreases flow through nozzle N1 and increases flow through nozzle N2, resulting in a pressure differential between chambers C1 and C2. Since C1 pressure is greater, the plunger (UVT1) moves to the right, UCT2 is ported to tank, and UCT3 receives servo pressure. The control pressure at stroking piston UCT3 is now greater than the pressure at stroking piston UCT2, causing the tilt plate to move in a clockwise direction. Clockwise movement accelerates the mount during increasing orders and decelerates it during decreasing orders. For negative signals, UVT1 plunger action is reversed and the flapper shifts to block the flow through N2, causing the tilt plate to move counterclockwise.

When plunger UVT1 moves from center, the feedback spring applies a torque to the armature. This torque, which is proportional to the plunger displacement, opposes the torque developed by the force motor. As the order is complied with, and as response causes the signal to decrease, the torque on the armature returns the flapper to neutral (fig. 6-17, view B).

The servo valve has a mechanical override device that does not affect valve operation under normal conditions. When the limit-stop system assumes control of the power drive, however, the mechanical override device positions the servo valve regardless of the signal input to the force motor coils. Whenever the limit-stop system is in control, a protective device (a 3K resistor) is placed in series with the output from the stroke servo amplifier to prevent damage to the force motor.

LIMIT-STOP MECHANISM

The limit-stop mechanisms prevent the gun from moving beyond its designed limits and damaging the ships's structure or gun mount equipment. If a limit is reached while the gun is moving or the mount is rotating, the limit-stop mechanism returns the A-end tilt plate of the hydraulic transmission unit to neutral and stops gun movement. The components of the limit-stop mechanisms are the wobble gear, the limit-stop assembly, the limit-stop lever, and the override device. The function of each of these components, illustrated in figure 6-18, will be addressed separately.

Wobble Gear

The wobble gear functions as a differential speed reducer in the limit-stop mechanism. (A mechanical differential gear arrangement adds or subtracts mechanical inputs.) The train and elevation limit-stop mechanisms are similar in operation; however, only the train limit-stop mechanism is discussed in detail.

When the mount is moving in train, response gearing from the train B-end rotates the wobble gear B-end input. The wobble gear transfers B-end rotation to the limit-stop output. In addition, the A-end stroking piston, through the limit-stop, adds a lead to the wobble gear. This lead, proportional to train velocity, allows time for smooth deceleration of the mount.

A limit-synchronized switch (SIT-4) and cam are safety features which stop the train power drive whenever the limit-stop crank arm is beyond 60° from its neutral position in either direction. If, during maintenance or repair, the crank arm is displaced 180° out of position, limit-stop action would be reversed and the mount would drive into the limit stops and serious damage could result. To prevent this, the limit-synchronized cam opens limit switch SIT-4, which in turn opens the train contactor circuit to the train motor, and stops the gun mount movement.

Limit-Stop Assembly

The limit-stop assembly consists of eight limit stops, central shaft, and a drive gear. The eight limit stops are divided into two sets of four stops each. One set forms the clockwise train limit, and the other set forms the counterclockwise train limit. Each set consists of one limit stop splined to the central shaft, two limit stops free to rotate on the central shaft, and one adjustable limit stop fixed to the limit-stop housing.

For an analysis of limit-stop operation, assume that the mount is training clockwise. In clockwise rotation, only the clockwise limit stops are used; the counterclockwise limit stops rotate freely.

As the mount trains, the drive gear, center shaft, and limit stops 1 and 8 are rotated counterclockwise by B-end response. As limit stops 1 and 8 rotate, the projections on their cam surfaces capture limit stops 2 and 7. The counterclockwise stops 1, 2, and 3 are moving away from stationary limit stop 4 and have no effect on clockwise limit-stop operation. As the mount continues its rotation, limit stop 7 captures limit stop 6 and moves toward stationary limit stop 5. When the mount reaches its rotation limit, limit stop 6 strikes the stationary clockwise limit stop 5 and locks the entire limit-stop assembly.

With the limit-stop output locked, the wobble gear can no longer transfer B-end rotation to the limit-stop assembly. Since the mount and the B-end response gear are still rotating, the wobble gear transfers B-end rotation to the limit-stop lever.

Limit-Stop Lever

One end of the limit-stop lever is attached to a cam surface linked to the A-end stroking piston.

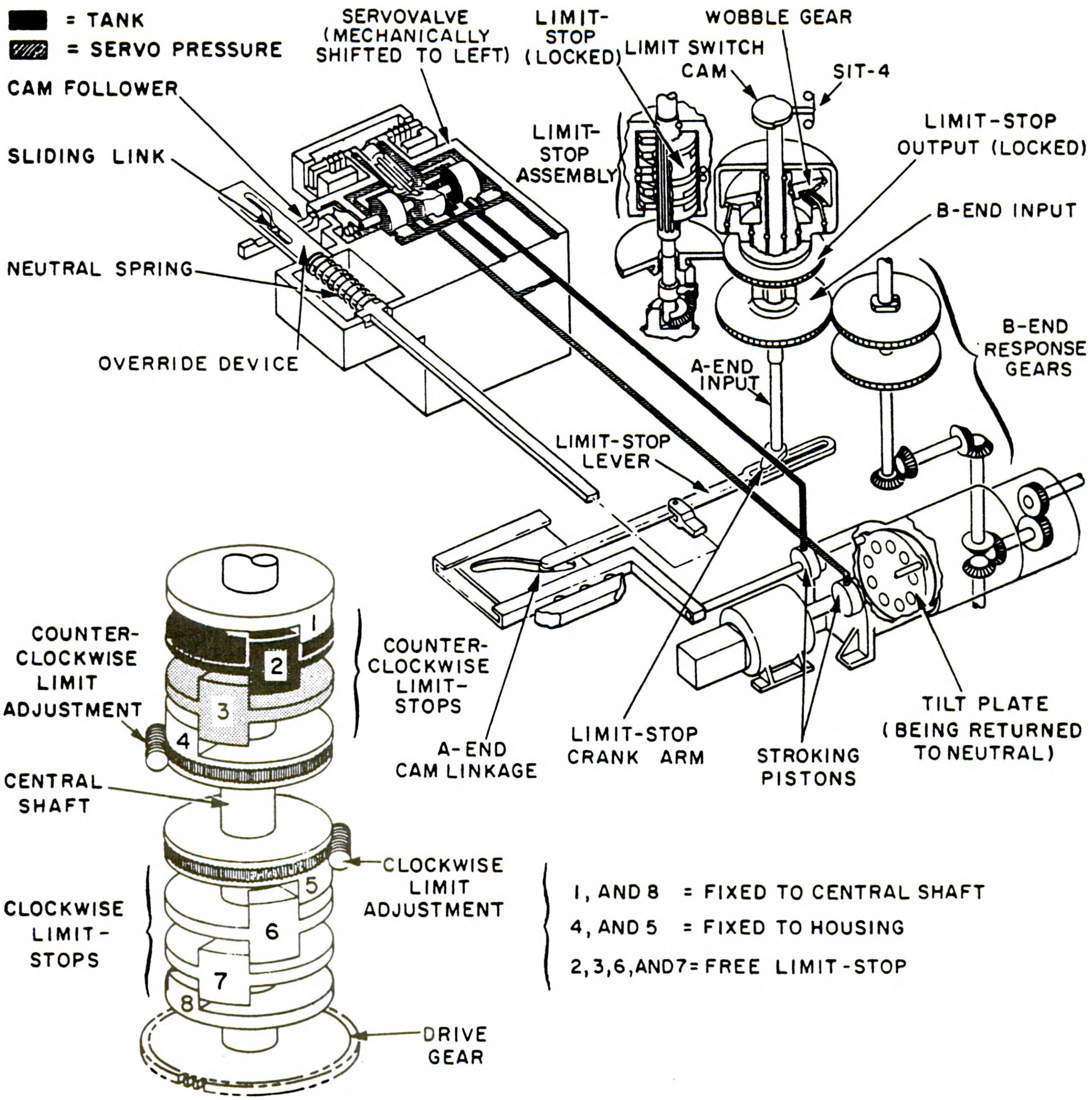


Figure 6-18.—Limit stops at clockwise limit.

The other end is attached to the wobble gear by the limit-stop crank arm.

Since one end of the limit-stop lever is held hydraulically by the A-end stroking piston, movement from B-end response is transmitted mechanically to the override device by the limit-stop crank arm. The override device positions the servo valve to port hydraulic fluid to the opposite stroking piston to decelerate the gun and stop gun movement.

Override Device

The override device is connected to the servo valve by a sliding link. During normal operation, the movement of the servo valve as it responds to the electrical order signal is not great enough to contact the override device. When a limit-stop action occurs, the diagonal portion of the override device raises the cam follower and the override device. The sliding link then contacts the upper shoulder of the servo valve, moving the servo valve piston to mechanically override the electrical signal to the force motor and decelerate the gun. A neutral spring holds the override device at neutral when the power drive is not under limit-stop control.

Q16. Module board PC2 amplifies what two signals?

Q17. What converts the electrical input supplied by the servo amplifier to a mechanical displacement?

NONPOINTING ZONE CUTOUT SYSTEM

The nonpointing zone cutout system prevents the gun from pointing toward the structure of the ship. The areas of ship structure that could be endangered, either through direct physical interference from the gun or by accidental firing, are called nonpointing zones. Figure 6-19 shows a simplified arrangement of the nonpointing zones aboard ship. Although a nonpointing zone system can be arranged on one, two, or three levels, the following text assumes that a three level nonpointing zone arrangement is in use.

The nonpointing zone cutout system receives position and position-plus-lead signals from the train and elevation systems. When position-plus-lead signals indicate that the mount is approaching a nonpointing zone, the nonpointing zone cutout system mechanically overrides gun laying orders and detours the gun around the zone. When position signals indicate that the gun has moved away from a nonpointing zone, the gun laying orders resume control of the mount.

NOTE: The nonpointing zone cutout system actuates the train and elevation limit-stop mechanisms to override gun laying orders.

Position signals are produced by one set of cams and cam switches located in each receiver-regulator (fig. 6-20, train only). Each cam set consists of four cams rotated by B-end response gearing and four cam-actuated switches. Three cams indicate train position, three indicate elevation position, while the fourth cam in each set is a spare.

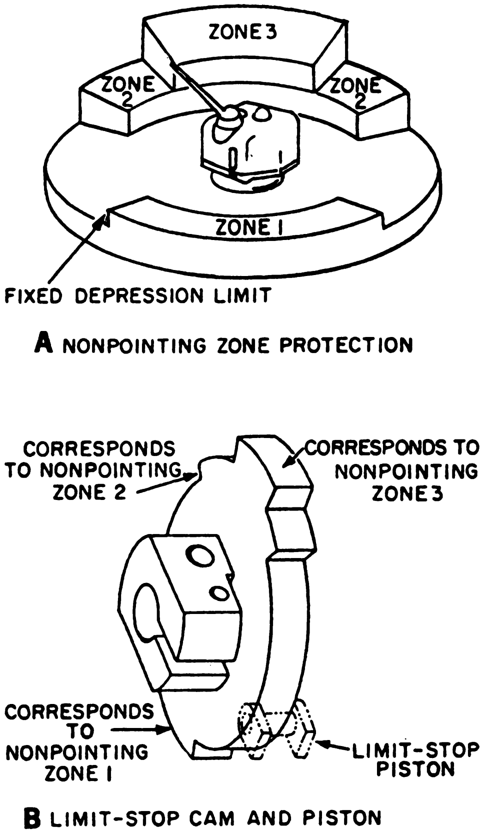

ZONE 3
ZONE 2
ZONE 2
ZONE I
FIXED DEPRESSION LIMIT
A NONPOINTING ZONE PROTECTION
CORRESPONDS TO NONPOINTING ZONE 2
CORRESPONDS TO NONPOINTING ZONE 3
CORRESPONDS TO NONPOINTING ZONE I
LIMIT-STOP PISTON
B LIMIT-STOP CAM AND PISTON

Figure 6-19.—Typical nonpointing zone system.

Three of the cams in each cam stack correspond to the three elevation levels and the three train positions. Whenever the gun enters one of these positions, or levels, regardless of the gun position or gun elevation, the cams for that zone open its associated switch to actuate the train and elevation limit-stop mechanism.

There is also a set of four position-plus-lead cams and cam switches in each receiver-regulator. Three of these cams indicate train or elevation position-plus-lead and the fourth cam indicates train direction forward or aft (train system only). The fourth elevation position-plus-lead cam is a spare.

Each position-plus-lead cam set is rotated by B-end response gearing through the wobble gear of its respective system. The A-end input to the wobble gear rotates the position-plus-lead cams ahead of the true position of the mount in proportion to train velocity. The velocity lead causes the position-plus-lead switches to open before the mount actually reaches a nonpointing zone to allow time for gun mount deceleration.

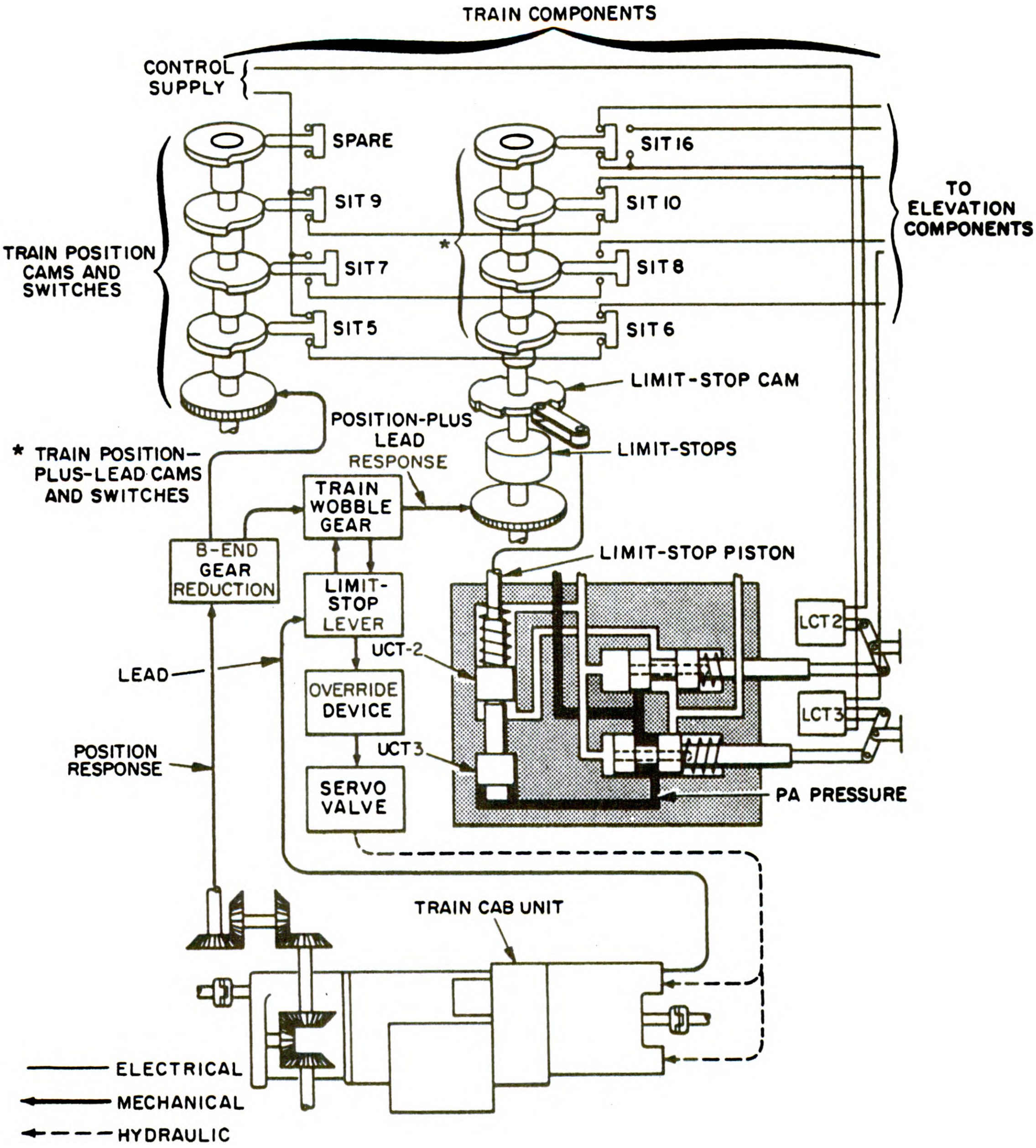


Figure 6-20.—Nonpointing zone cutout system functional diagram.

LIMIT-STOP ACTUATION (TRAIN)

The train limit-stop mechanism is actuated by deenergizing one of the two nonpointing zone solenoids (LCT-2 and LCT-3) in the train nonpointing zone valve block (fig. 6-20).

Solenoid LCT-3 deenergizes to prevent training into nonpointing zone 3 whenever the gun is depressed below elevation level 3.

NOTE: The elevation cam switches control the deenergizing of the train nonpointing zone solenoids and the train cam switches control the elevation nonpointing zone solenoids.

Solenoid LCT-2 is deenergized under two separate conditions to prevent training into either nonpointing zone 1 or nonpointing zone 2. LCT-2 deenergizes for nonpointing zone 2 when the gun depresses into elevation level 2 when the mount is in the aft half of the training circle (from 180° relative to ± 90° relative). LCT-2 deenergizes for nonpointing zone 1 when the gun depresses into elevation level 1 while the mount is in the forward half of the training circle (from 0° relative to ± 90° relative).

When either of the train nonpointing zone solenoids is deenergized, it shifts its associated control valve inside the train nonpointing zone valve block. Servo pressure (PA) passes through the lands of one of the solenoid valves to the bottom of one of the two train limit-stop piston sections (UCT-2 or UCT-3). The larger area at the bottom of each piston allows PA pressure to shift one or both pistons up to engage the train limit-stop cam.

The train limit-stop piston has two sections: UCT-2 and UCT-3. When PA is ported to either section of the piston, the piston moves up. When LCT-3 deenergizes, PA is ported to the bottom of UCT-3; when LCT-2 deenergizes, PA is ported to the bottom of UCT-2. Since section UCT-2 is longer than UCT-3, the limit-stop piston is shifted farther up when LCT-2 deenergizes. When the piston shifts up, it is in a position to engage the train limit stop cam for zone 1 or zone 2. The extension of the piston determines which raised area on the limit-stop cam will be engaged.

Train Limit-Stop Cam

The train limit-stop cam is splined to the central shaft of the train limit-stop assembly below the position-plus-lead cam stack (fig. 6-20). The edge of the limit-stop cam has three raised areas that correspond to the train positions of the nonpointing zones. The area for zone 3 is the highest of the three; the areas for zones 1 and 2 are the same height, but are on opposite sides of the cam. When the limit-stop piston is extended, one of the three raised areas on the cam rotates against the piston, locking both the cam and the limit-stop shaft. The extension of the piston depends on which solenoid is deenergized. This, in turn, determines which raised area locks against the piston.

When the limit-stop shaft is locked, the train limit-stop mechanism prevents the mount from moving farther in train (limit-stop operation explained early in this chapter). Although gun laying signals are still applied to the train servo valve, the limit-stop mechanism overrides these signals to prevent the mount from training into a nonpointing zone. When the elevation system raises the gun out of the elevation level of the nonpointing zone, the zone solenoid is reenergized, the limit-stop piston is retracted, the train limit-stop shaft is released, and the mount is free to train over the zone.

Combined Train and Elevation Cutout Operation

The nonpointing zone cutout system deals with specific train and elevation angles. Any time the gun mount moves above, below, in, or out of these specific angles, cutout switches supply indications to the gun laying servo system.

Figure 6-21 shows the route of a loaded gun training right and depressing toward nonpointing zone 3 while tracking an air target. Circled numbers along the gun's route indicate that sequence of cutout operation.

Since the position-plus-lead switches are the first switches to open and deenergize the nonpointing zone solenoids as the gun mount approaches a zone, and the position switches are the last to close as the gun travels away from the zone, figure 6-21 shows only the opening and closing points of the position switches. To better understand what actually takes place in this system, follow the functional diagram in figure 6-20 as each of the points in figure 6-21 is discussed.

At point 1, the elevation switch for nonpointing zone 3 opens. This action deenergizes

ANSWERS TO QUESTIONS Q16 AND Q17.

A16. 1X and 36X position error signals.

A17. LCT-2 and LCT-3.

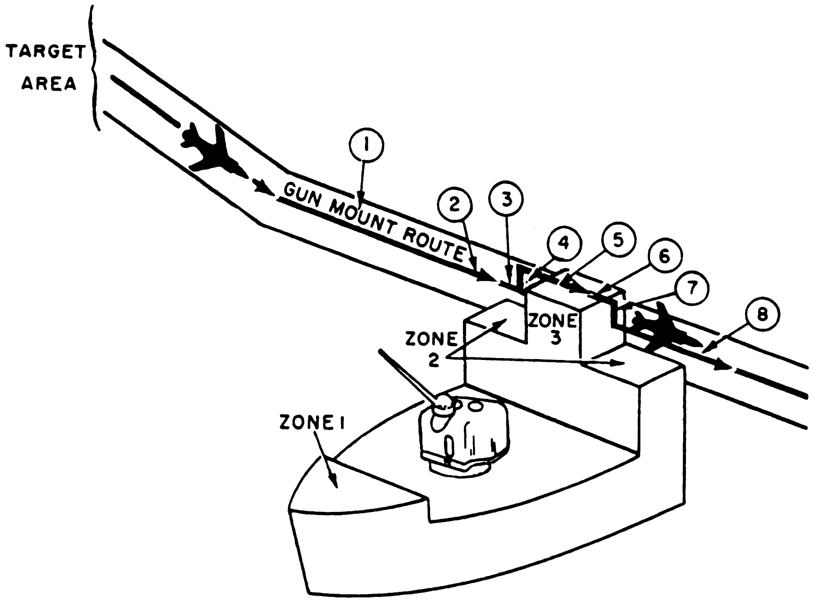


Figure 6-21.—Sequence of cutout operation.

train zone 3 solenoid LCT-3 causing UCT-3 to extend and drive the limit-stop piston to a position where it contacts the zone 3 area of the train limit-stop cam. The limit-stop piston, however, does not halt the stop cam until the zone 3 area of the limit-stop rotates into a position to contact it. The deenergizing of LCT-3 supplies the train system with an indication that the gun has depressed below the zone 3 elevation limit.

At point 2, the train switch for zone 3 opens, causing the elevation limit-stop system to take control. After a short transition period required to shift servo control from the elevation amplifier to the elevation limit-stop system, the mount stops depressing and starts elevating under limit-stop control.

At point 3, the train nonpointing zone cam contacts the limit-stop piston, supplying a stop order to the train limit-stop system. Control of the train power drives passes from the train amplifier to the train limit-stop system, causing the train power drive to decelerate and stop under limit-stop control.

At point 4, the mount has stopped training, but continues elevating through the elevation limit-stop system.

At point 5, the elevation zone 3 position switch closes, energizing LCT-3 (elevation above zone 3) causing UCT-3 to retract. Since train stop cam movement is no longer restricted and a right train order is in effect, the mount begins to train across the top of zone 3.

At point 6, the gun cannot follow the depression order from the amplifier because the gun mount is not past zone 3, and the elevation limit-stop system holds the gun at a fixed elevation above zone 3.

At point 7, the zone 3 train position switch closes and the elevation limit-stop piston retracts. This action frees the elevation limit-stop rack and the gun begins to synchronize with the depression order from the elevation amplifier.

At point 8, the train and elevation orders are synchronized and the gun mount can resume tracking the target.

POWER-OFF BRAKE

The Mk 42 Mods 9 and 10 gun mounts have power-off brakes which serve to (1) stop the gun when power is lost; (2) secure the equipment against pitch and roll of the ship when the system is inactive; and (3) provide a means through which to train and elevate or depress the mount with an air motor during power-off operation for maintenance, emergency operation, or installation procedures. Figure 6-22 shows the important parts of the power-off brake. The brake shaft extends out of the brake housing and connects to the equipment it controls. The friction disks mesh alternately with the brake shaft and the brake housing. Springs force the pressure plate against the friction disks. The connecting rod joins the piston to the pressure plate.

Power Operation

Hydraulic pressure releases the power-off brake and spring pressure sets it. Since the operation of the train and elevation power-off brake is identical, only the train brake is discussed. When the train system is activated, the power-off brake is released by hydraulic pressure and the mount is free to turn. When the train brake solenoid LHT1-LC1 is energized (fig. 6-23, view A), it shifts brake release valve UVT20 down to port PA to the left side of brake release piston UCT6. When piston UCT6 is shifted to the right, the connecting rod attached to the pressure plate pulls the plate away from the friction disks, compressing the compression springs. The brake shaft is then in the disengaged position and can turn easily with the rotation of the equipment it controls.

When the system is shut down or power is lost during normal operations, LCT1-LC1 is deenergized. Piston UVT20 shifts up and closes the PA port to the brake piston (fig. 6-23, view B). The compression springs force the pressure plate to contact the disks and the disks come in hard contact with each other. The brake shaft is then connected to the brake housing through the friction disks and worm gear.

When the power-off brake is stopping a piece of equipment, the worm gear transmits force to the worm shaft. However, the pitch of the worm shaft is too low to result in a transfer of motion from the worm gear to the worm shaft. The worm shaft is coupled directly to the air

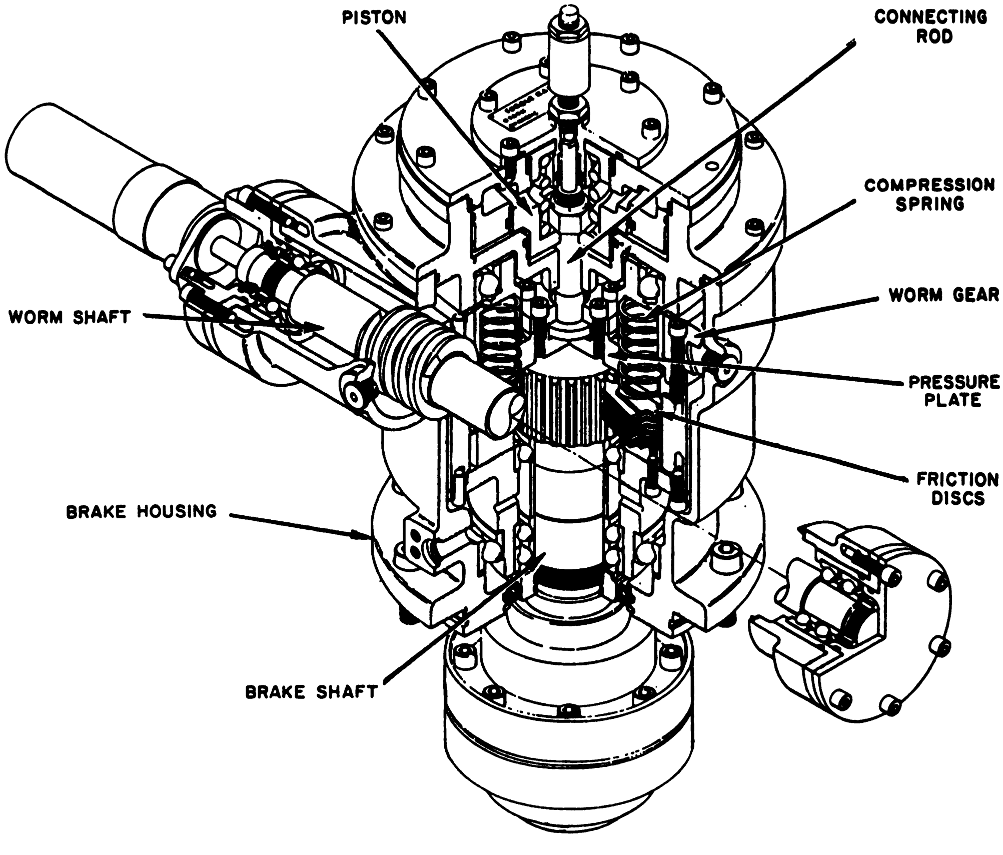


Figure 6-22.—Power-off brake.

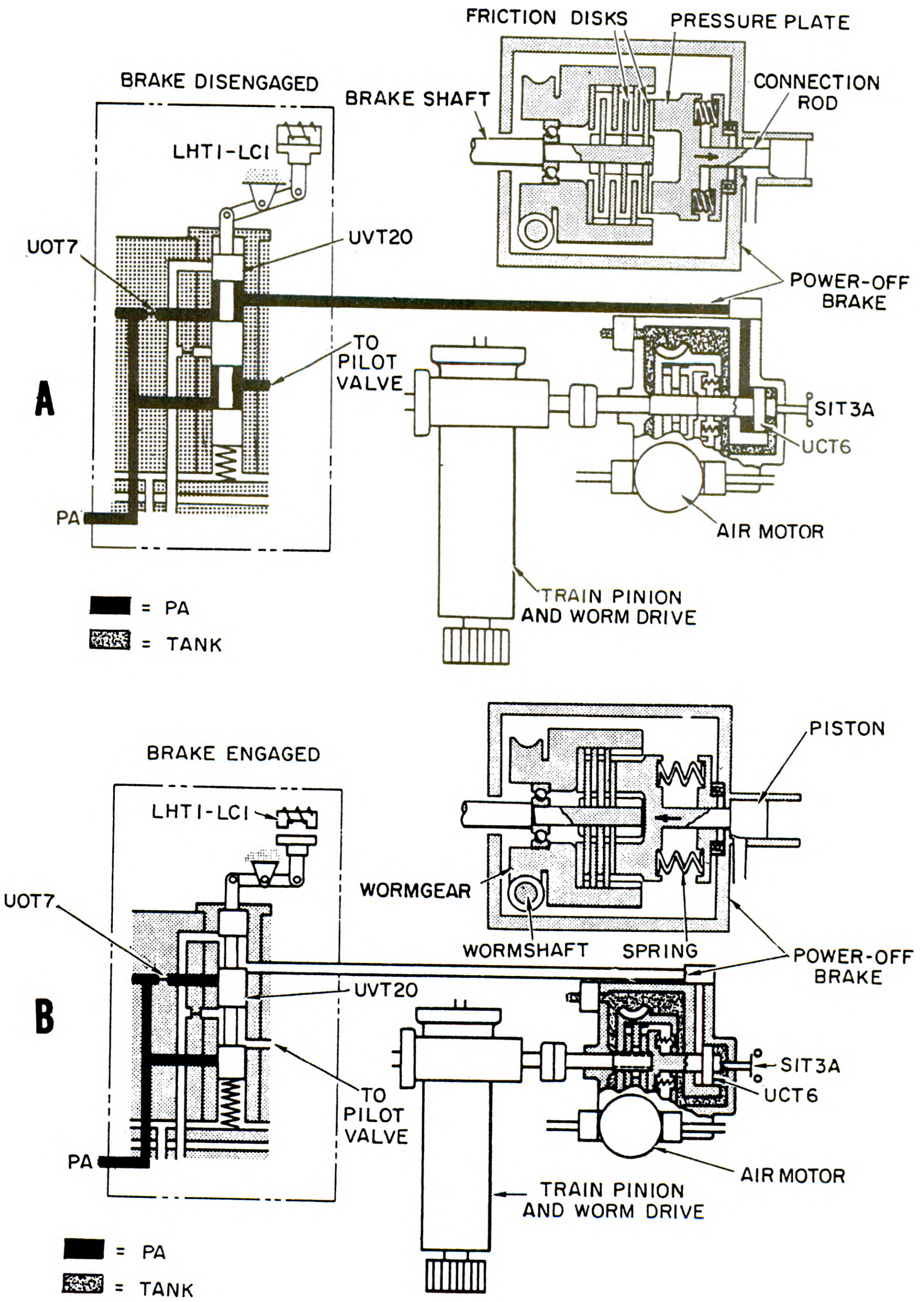


Figure 6-23.—Power-off brake schematic diagram.

motor (fig. 6-24) and rotates in the same direction as the air motor.

Air Motor Operation

Air motor operation is not possible if the brake is disengaged, because the friction disks are not in positive contact with each other and the brake shaft turns freely without exerting force in the worm gear. In the engaged position, the power-off brake transmits rotation from the air motor to the equipment associated with the brake (train or elevation).

To train the mount, air is ported through manual pneumatic control valve XVT1 (fig. 6-24) and through either train limit pneumatic cutoff valve XVT2 or XVT3 to air motor XPT1. Spring-loaded valve XVT1 can be in one of three positions. Unless manually positioned otherwise, the valve is at neutral and no air pressure is applied to the motor. With the handle of XVT1 held in the clockwise position, air is ported to the right side of XVT1 through XVT3 to the air motor, causing the motor to turn clockwise. Since the output shaft of the motor is splined to the worm shaft, the worm shaft turns the worm gear, which drives the brake shaft. The brake shaft drives the train pinion to train the mount clockwise. For counterclockwise train, the handle of XVT1 is held to the left, the counterclockwise position.

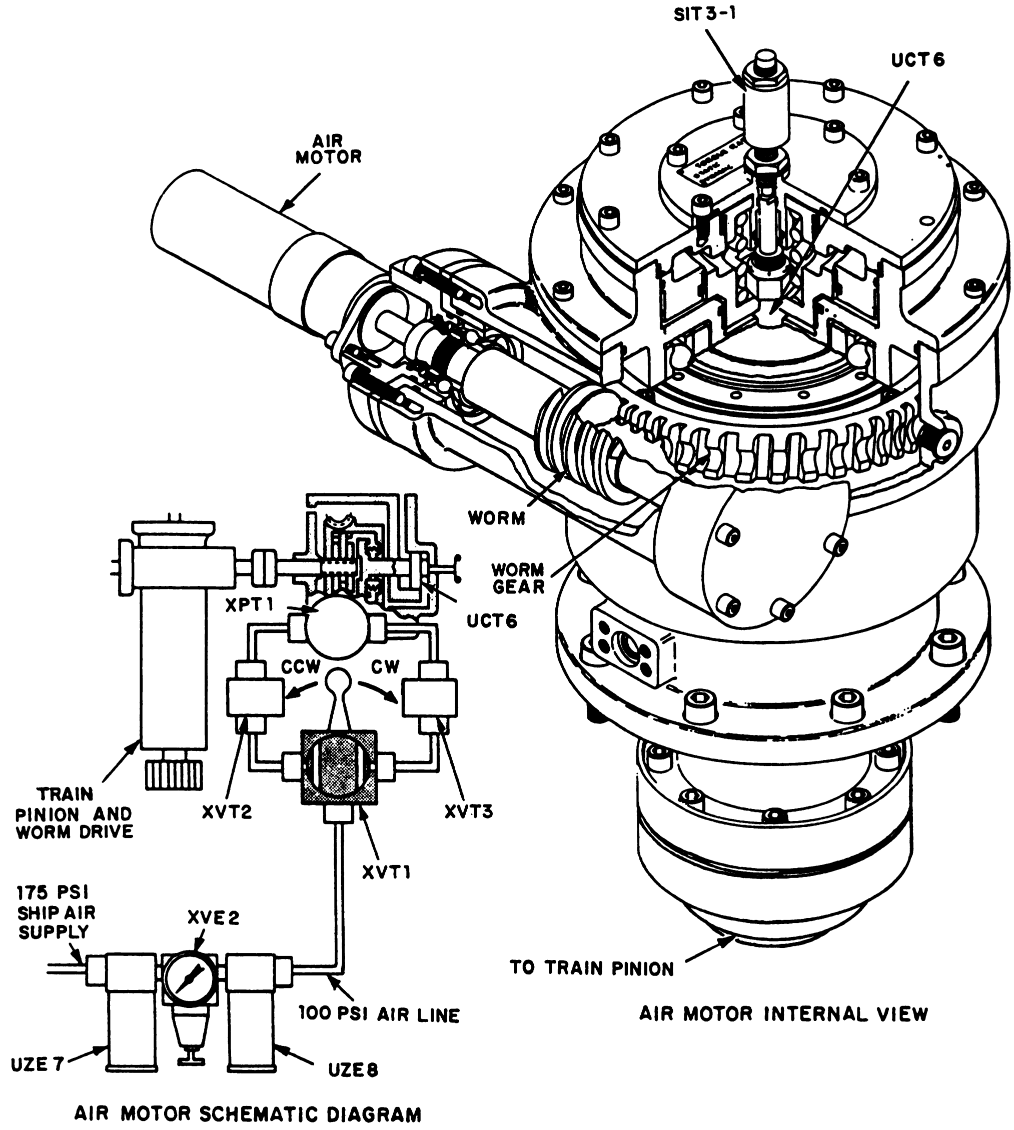


Figure 6-24.—Train power-off drive air motor.

Q18. The train limit-stop mechanism is actuated by deenergizing what two solenoids?

Q19. What is the purpose of the power-off brake?

5"/54 MK 45 GUN MOUNT CONTROL EQUIPMENT

The hydraulic power drive control equipment for the 5"/54 Mk 45 gun mount is essentially the same as for the 5"/54 Mk 42 Mods 9 and 10 gun mounts, except that the Mk 45 gun mount has no OMC unit. For more information on this gun mount, refer to OP 3392, *5-Inch 54-Caliber Gun Mount Mk 45 Mod 0; Description, Operation and Maintenance.*

16" 3-GUN TURRET

The 16" turret has two methods of control—automatic and hand. The type of control to be used is selected at the trainer's station by means of a selector lever.

AUTOMATIC CONTROL

In automatic control, a signal from a remote source, received electrically at the receiver-regulator, controls hydraulic valves in the receiver-regulator. These valves control the output to the hydraulic pump (A-end) which, in turn, controls the output of the hydraulic motor (B-end), causing the turret to automatically follow the remote signal.

HAND CONTROL

In hand control, the receiver-regulator is bypassed. The hand wheels are mechanically connected to a hydraulic servo control valve in the control box. The control valve ports servo pressure through the control transfer valve to the A-end servo piston. The servo piston moves the tilting box in response to hand wheel motion. The B-end rotates the turret at a rate corresponding to the speed and direction of hand wheel rotation.

RECEIVER-REGULATOR

The receiver-regulator for the 16" turret (fig. 6-25) is an electric-hydraulic instrument enclosed

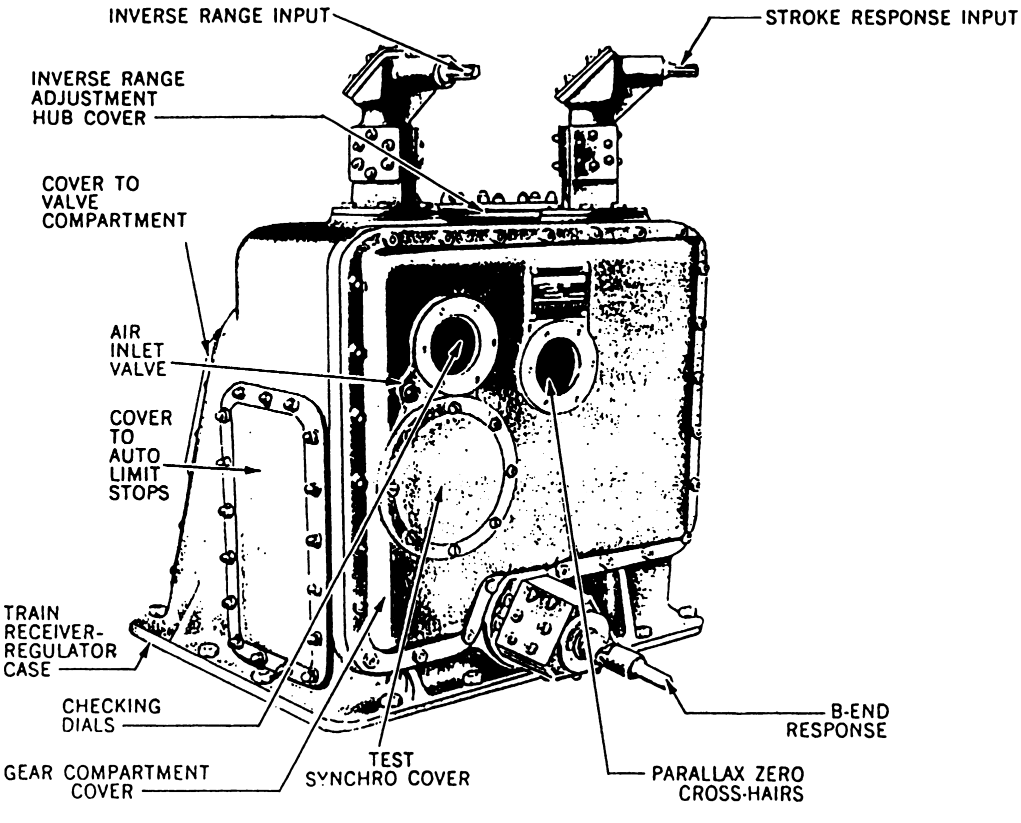

INVERSE RANGE INPUT
STROKE RESPONSE INPUT
INVERSE RANGE ADJUSTMENT HUB COVER
COVER TO VALVE COMPARTMENT
AIR INLET VALVE
COVER TO AUTO LIMIT STOPS
TRAIN RECEIVER-REGULATOR CASE
CHECKING DIALS
B-END RESPONSE
GEAR COMPARTMENT COVER
TEST SYNCHRO COVER
PARALLAX ZERO CROSS-HAIRS

Figure 6-25.—Train receiver-regulator.

in a case which is divided into two compartments. One compartment contains the electric synchros and related gearing; the other contains the hydraulic valve blocks and related devices. Covers are provided to permit access to various internal components. The gear compartment cover is provided with an air valve for pressurization, and windows for checking dials.

The internal components of the receiver-regulator, most of them identified in figure 6-26, include the fine and coarse synchros, parallax computer, turret response gear, stroke response gear, limit-stop device, limit-stop valve (V34), stabilizing valve (V1), stabilizing linkage (L2), automatic stroking valve (V2), synchronizing valve (V3A), synchronizing linkage (L3), pressure regulator valve (V42), stabilizing piston (P1), amplifier piston (P3), amplifier linkage (L1) and hydraulic vibrator. To better understand the components of the receiver-regulator, let's examine them in more detail.

FINE AND COARSE CONTROL SYNCHROS

Turret train orders are transmitted electrically to the receiver-regulator by the synchro circuits. Both the coarse and fine synchros are bearing-mounted so that the stator of the synchros can be rotated by parallax correction, B-end train response, and A-end stroke response. The rotor of the coarse synchro positions the synchronizing valve V3A through the synchronizing linkage L3. The rotor of the fine synchro positions the fine synchro valve V3 through the amplifier linkage L1.

PARALLAX COMPUTER

The parallax correction is computed for the horizontal distance between the director and the turret, and is derived from train angle and parallax range. The parallax computer mechanism enters a mechanical correction to the train order signal and the angle of turret train. The parallax value is variable, depending upon three factors:

1. The base line distance from the director to the turret
2. The range of the target
3. The angle of turret train

For any angle of turret train except dead ahead or dead astern, the parallax correction varies inversely with the range (the maximum correction when the target is abeam at short range, and the minimum correction when the target is a few degrees ON the BOW). The parallax computer receives input from the train indicator and the B-end response gear. The two values are continuously converted to mechanical correction. The movement of the gears add parallax correction to the input of the fine and coarse synchros.

TURRET RESPONSE GEAR

The train (B-end) response gear drives one input gear of the differential that rotates the stators of the coarse and fine synchros through a gear train assembly within the receiver-regulator case. From the right B-end, train response is simultaneously transmitted to the train and elevation indicators, to the transmission control case, and to the receiver-regulator. In the receiver-regulator, the B-end response combines with parallax correction to rotate the stators of the coarse and fine synchros. B-end response and stroke response are combined in a differential to position limit-stop valve V34 through a correcting link from the train limit-stop drive.

STROKE RESPONSE GEAR

The A-end stroke response is a mechanical input received from the gear box attached above the A-end control case. The gear box receives tilting box motion through the A-end control case and steps up the motion to a ratio of 15 to 1. This new value is transmitted as stroke response to the

ANSWERS TO QUESTIONS Q18 AND Q19.

A18. LCT-2 and LCT-3.

A19. Stop the gun when power is lost, secure the equipment against pitch and roll, and provide a means to move the mount with the air motor when power is off.

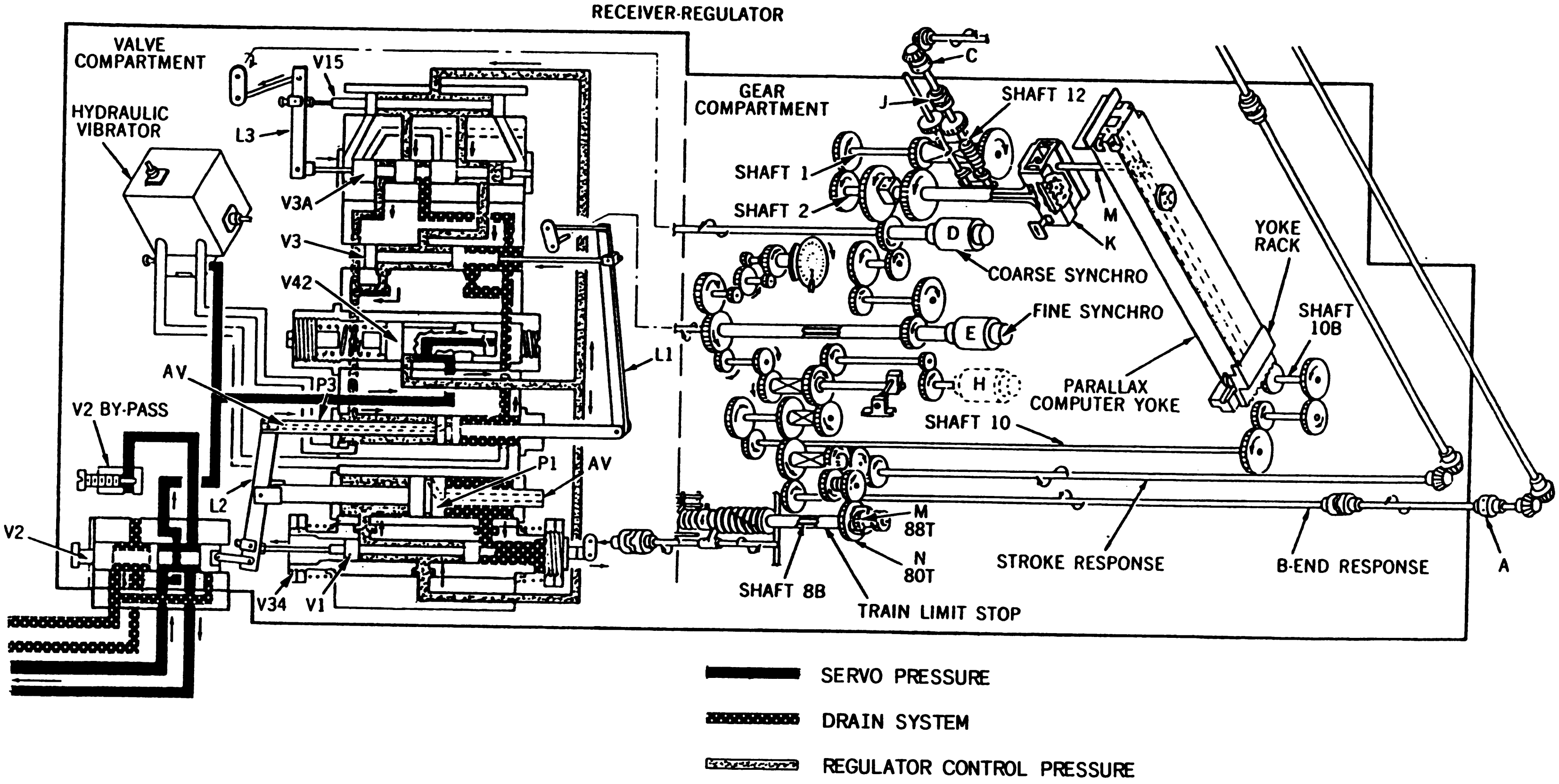


Figure 6-26.—Train receiver-regulator, functional diagram.

receiver-regulator by means of shafts connected to an adjustable coupling. In the receiver-regulator, stroke response combines with B-end response through differential gearing to position the limit-stop valve V34 through the train limit-stop drive. Stroke response represents turret training speed; it is combined with B-end (turret position) response to make V34 operate faster at high speeds than it does at low speeds as the turret approaches its limit.

LIMIT-STOP DEVICE

The automatic train limit stop receives a combination of the angle of turret train and the speed train through a mechanical differential. The device consists of a series of discs and lugs, which are free to rotate on a shaft. Each discs contains a pin that extends on either side of the disc. The discs are assembled alternately on a common shaft with the lugs. The lugs engage the pins as the drive shaft input rotates. As the discs rotate, the pins engage the successive lugs until the entire assembly rotates as a unit. The last lug to be engaged operates a cam that rotates the limit-stop drive shaft. The shaft then moves valve V34, which is also the sleeve for the stabilizing valve (V1) (fig. 6-26).

Limit-Stop Valve

Limit-stop valve (V34), located in a valve block at the bottom of the receiver-regulator, is positioned by the movement of a crank which is actuated by the limit-stop device. V34 is normally centered by a spring at either end. When displaced from center by the limit-stop device, V34 shifts servo pressure flow to, and drains it from, stroking piston P2, to decelerate and stop the turret at its preset limits.

Stabilizing Valve

Stabilizing valve V1, located within the limit-stop valve V34 body, acts with the stabilizing piston P1, to prevent overtravel of the turret. Movement of P1 positions amplifier piston P3 and amplifier linkage L1, and also moves V1 back to its original position.

Stabilizing Linkage

Stabilizing linkage L2 is mounted in a vertical position in the valve compartment of the receiver-regulator. At its upper end, L2 is connected to the amplifier piston P3. The middle of L2 is connected to the stabilizing piston P1. At its lower end, L2 is connected to both the automatic stroking valve V2 and the stabilizing valve V1.

AUTOMATIC STROKING VALVE

Automatic stroking valve V2 is positioned by the stabilizing linkage L2. V2 ports servo pressure flow to, and drains it through, the control transfer valve V3B.

SYNCHRONIZING VALVE

Synchronizing valve V3A and the synchronizing pilot valve V15 are located in the upper part of the receiver-regulator valve compartment. Both valves are positioned by the synchronizing valve linkage L3, which is actuated by rotation of the rotor of the coarse synchro. V15, when centered, ports regulator control pressure to the fine synchro valve V3 as long as the turret position is within 3° of the turret train order. V3 then controls servo piston movement through amplifier piston P3, stabilizing linkage L2, and automatic stroking valve V2. When the turret position is more than 3° away from turret train order, V3A cuts off regulator control pressure to V3 and ports the pressure directly to P3 to drive the turret at full speed toward its synchronized position.

Q20. What two methods of control are used to move the 16" turret?

Q21. Regarding the 16" turret, how many factors affect the parallax value?

Q22. What positions the automatic stroking valve (V2)?

SAFETY

Practical safety features are built into Navy equipment to eliminate potential hazards to personnel. Since familiarity with equipment leads to carelessness, observation of all safety precautions and rules is mandatory.

OP 3347, *United States Ordnance Safety Precautions*, is the official publication for ordnance safety precautions, and is applicable to both sea and shore establishments of the Navy.

MOVING EQUIPMENT

All personnel taking part in or observing operation of power equipment should remain alert, keep clear of moving parts, and be thoroughly familiar with the safety precautions applicable to that equipment. At no time should skylarking be allowed in the vicinity of operating power equipment.

When making phase balance or feedback adjustments to servo amplifiers, or when adjusting receiver-regulators, the gun mount and/or gun barrel may drift. The train warning bell should be sounded, and you should ensure that the area around the mount is clear.

HYDRAULIC EQUIPMENT

Hydraulic systems operate under hydraulic pressures ranging from approximately 100 psi to 2,000 psi. If not properly respected, these pressures could present hazards to personnel. The following safety rules should be observed:

1. Never disconnect hydraulic lines or disassemble hydraulic equipment when the hydraulic system power motor is running. In some accumulator systems, system pressures can remain within the system for hours, and even days, after the power motor has been stopped.
2. Never disconnect hydraulic lines or disassemble hydraulic equipment until the accumulators have been manually dumped to tank.
3. Only competent qualified personnel should manually actuate switches, relay, solenoids, or valves on hydraulic systems under pressure. Even competent qualified personnel should exercise the utmost care, with the understanding that their actions may bypass built-in safety features of the system.
4. All hydraulic leaks should be reported immediately and corrected at the first opportunity. A small leak in a high pressure system appears as a fine spray or mist, which in some fluids, could be ignited by a spark and cause an explosion.

ELECTRICAL EQUIPMENT

Since weapons systems electrical equipment employs voltages up to 440 volts, which are extremely dangerous, only authorized personnel, who have been duly assigned for weapon systems upkeep, should work on this equipment.

Whenever possible, the main supply and power switches should be turned off and tagged before an electrical circuit is checked or overhauled. When electrical equipment has to be serviced or adjusted with the power covers removed and the circuits energized, the following safety rules should be observed:

1. Always work in the presence of, or with the assistance of, another person who is capable of rendering first aid.

2. Remove rings, watches, bracelets, and other metal items.

3. Do not change fuses or lamps in power panels when the electrical circuits are energized.

4. When making adjustments, use only tools with adequately insulated handles.

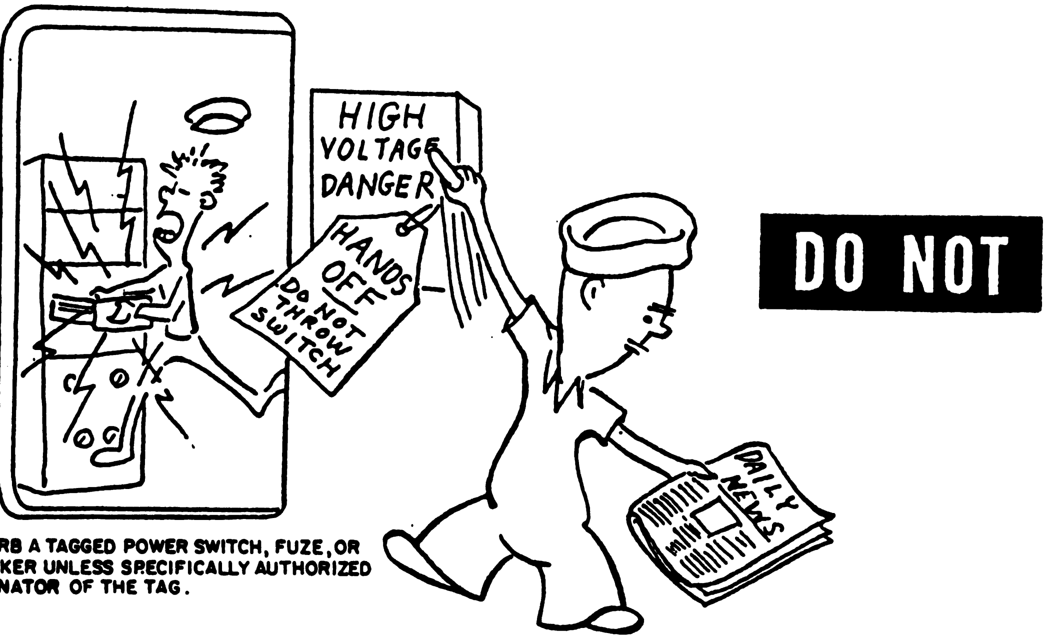
5. Keep hands, clothes, and shoes dry.

6. Ensure good insulation from ground with some suitable nonconducting material such as dry wood, several layers of dry canvas, or rubber mats of approved construction.

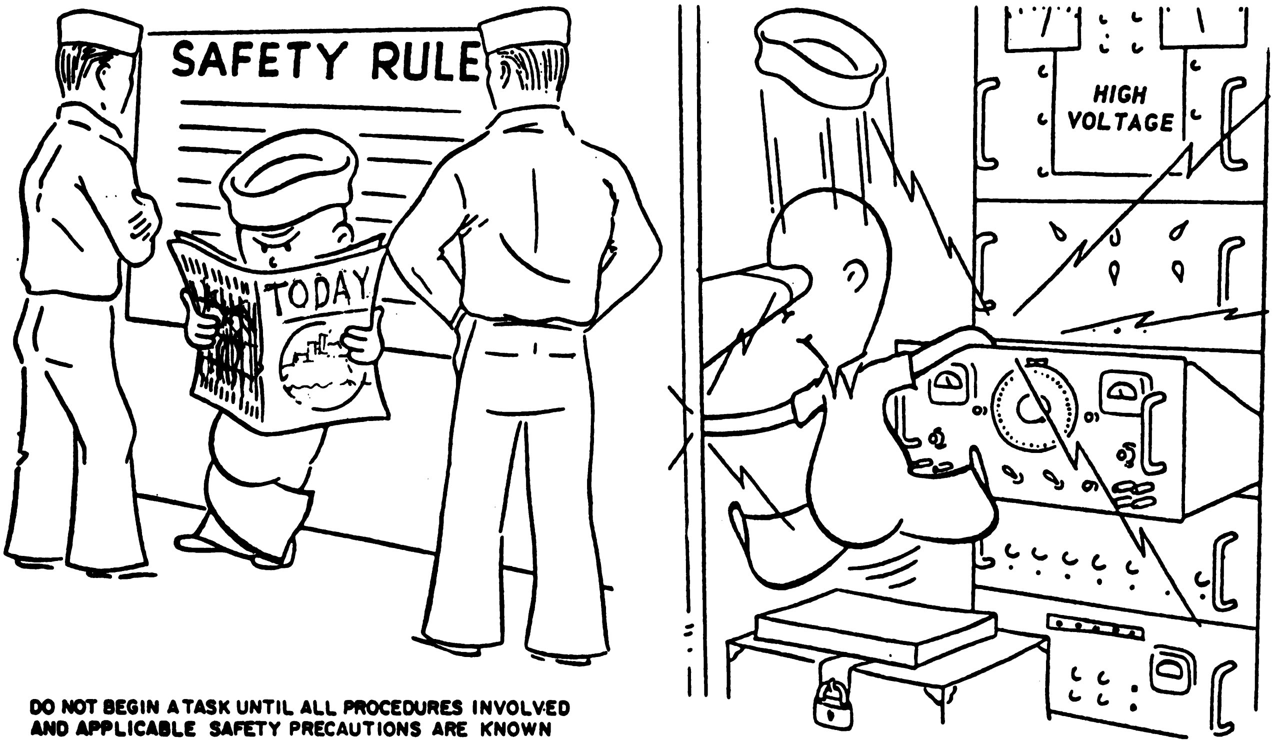
7. Always check an electrical circuit with a voltmeter to ensure that the circuit is open. Under certain conditions, due to capacitors that retain their charges, dangerous voltage potentials may still exist in circuits after the circuits have been deenergized.

8. Never remove, short circuit, or tamper with safety interlocks without specific authority. Periodic tests and inspections of these devices should be made to ensure that they are operating correctly.

Electrical safety precautions should be posted on or near each group of electrical or electronic equipment. Specific safety precautions pertaining to electrical or electronic equipment are normally contained in the technical manual for that equipment. Some of the DO NOTS are illustrated in figure 6-27.



DO NOT DISTURB A TAGGED POWER SWITCH, FUZE, OR CIRCUIT BREAKER UNLESS SPECIFICALLY AUTHORIZED BY THE ORIGINATOR OF THE TAG.



DO NOT BEGIN A TASK UNTIL ALL PROCEDURES INVOLVED AND APPLICABLE SAFETY PRECAUTIONS ARE KNOWN AND UNDERSTOOD.

DO NOT DEPEND ON THE EQUIPMENT SWITCH TO REMOVE POWER FROM EVERY PART OF THE EQUIPMENT.

Figure 6-27.—Safety depends on you.

ANSWERS TO QUESTIONS Q20 THROUGH Q22.

A20. Automatic and hand.

A21. Three.

A22. The stabilizing linkage (L2).

SAFETY DEPENDS ON YOU

SUMMARY

In comparing the control equipment of the 5″/38, the 5″/54, and the 16″ turret, we find that many of the devices and mechanisms in each of these systems will have similar functions. This is true, even though they may not physically resemble each other, or be called by the same name. In the 5″/38 drive, for instance, dithering is accomplished through an oscillator in the sump pump. In the 5″/54 drive, the same effect is accomplished by passing alternating current through the servo valve, thus keeping it constantly vibrating. Although the regulators for the different systems appear to differ in their individual makeup, they all control the power drives in response to electrical signals. So you see, one type of power drive system is not so different from another. Once you are familiar with one system, it should not be difficult to learn another. For more detailed information on specific systems, refer to that system's OP.

REFERENCE LIST

The following reference materials were used to develop the information presented in this chapter.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla. 1981.

5-Inch 38-Caliber Twin Gun Mount, NAVSEA OP 805, 3rd Revision, Commander, Naval Sea Systems Command, Washington D.C., Feb 1982.

5-Inch 54-Caliber Gun Mount Mark 42 Mod 9, NAVSEA OP 3851, 2nd Revision, Commander, Naval Sea Systems Command, Apr 1986.

16-Inch Three Gun Turret, NAVORD OP 769, Commander, Naval Sea Systems Command, Washington D.C., Aug 1982.

CHAPTER 7

FIRE CONTROL

As a Gunner's Mate, fire control is certainly no novelty to you. Nobody has to remind you that the Fire Controlman's work is as essential to the effectiveness of your ship's armament as is yours. As a GMG3 and GMG2, you had to learn what fire control systems were applicable to which gun systems. As a Gunner's Mate (Guns) First Class, you will be responsible for supervising subordinates in conducting various systems level tests. Three of the tests you will be conducting with your FC counterpart are (1) the Overall Combat System Operability Test (OCSOT), (2) the Daily System Operability Test (DSOT), and (3) the Interface Tests.

SYSTEM OPERABILITY TESTS

The system operability tests are the highest level of tests that can be performed to verify the readiness of the ship's combat system. These tests are normally performed on a weekly basis, but the periodicity of any PMS testing may vary, depending upon ship class. Typical combat systems and PMS testing hierarchies are shown in figure 7-1.

OVERALL COMBAT SYSTEM OPERABILITY TEST (OCSOT)

The overall combat system operability test (OCSOT) is the detection to engagement (DTE) assessment of selected major warfare capabilities and modes of the entire ship's combat system. The OCSOT checks the combined operation of all, or at least most, of the subsystems of a ship's combat system. The OCSOT is performed weekly. As a GMG1, you may be involved with several subsystems of this test that may or may not be applicable to your class ship. The DTE assessment entails processing a target from initial detection through identification, classification, threat evaluation, weapon assignment, weapon firing, and kill evaluation. All elements of the combat systems will be used and evaluated in this process.

The OCSOT is a deviation from normal PMS procedures. While it is designed to test the hardware and software, it requires operators to run the various subsystems. This affords the leading Gunner's Mate an opportunity to train subordinates on the workings of the overall weapon system.

Selected major warfare capabilities or modes tested by OCSOT include antisurface warfare, antiair warfare, antisubmarine warfare, and electronic warfare. All or selected combinations of these modes, can be tested singularly or in conjunction with one another. When available, additional testing can be conducted using Air Intercept Controllers (AICs) and Antisubmarine Air Controllers (ASACs). Discrepancies noted in any portion of the OCSOT are handled by the Ship's Electronic Readiness Team (SERT). This SERT may or may not include you as a Gunner's Mate. Once again, refer to figure 7-1 to see the interrelationships between the various subsystems.

Other level 1 PMS checks used in OCSOT problem resolution are the combat system operability test (CSOT), the combat system alignment test (CSAT), and the combat system interface test (CSIT).

Q1. At what interval is the Overall Combat System Operational Test (OCSOT) conducted?

Q2. Discrepancies noted in any portion of the OCSOT are handled by what team of technicians?

DAILY SYSTEM OPERABILITY TEST (DSOT)

The daily system operability test (DSOT) checks the operation associated with fire control

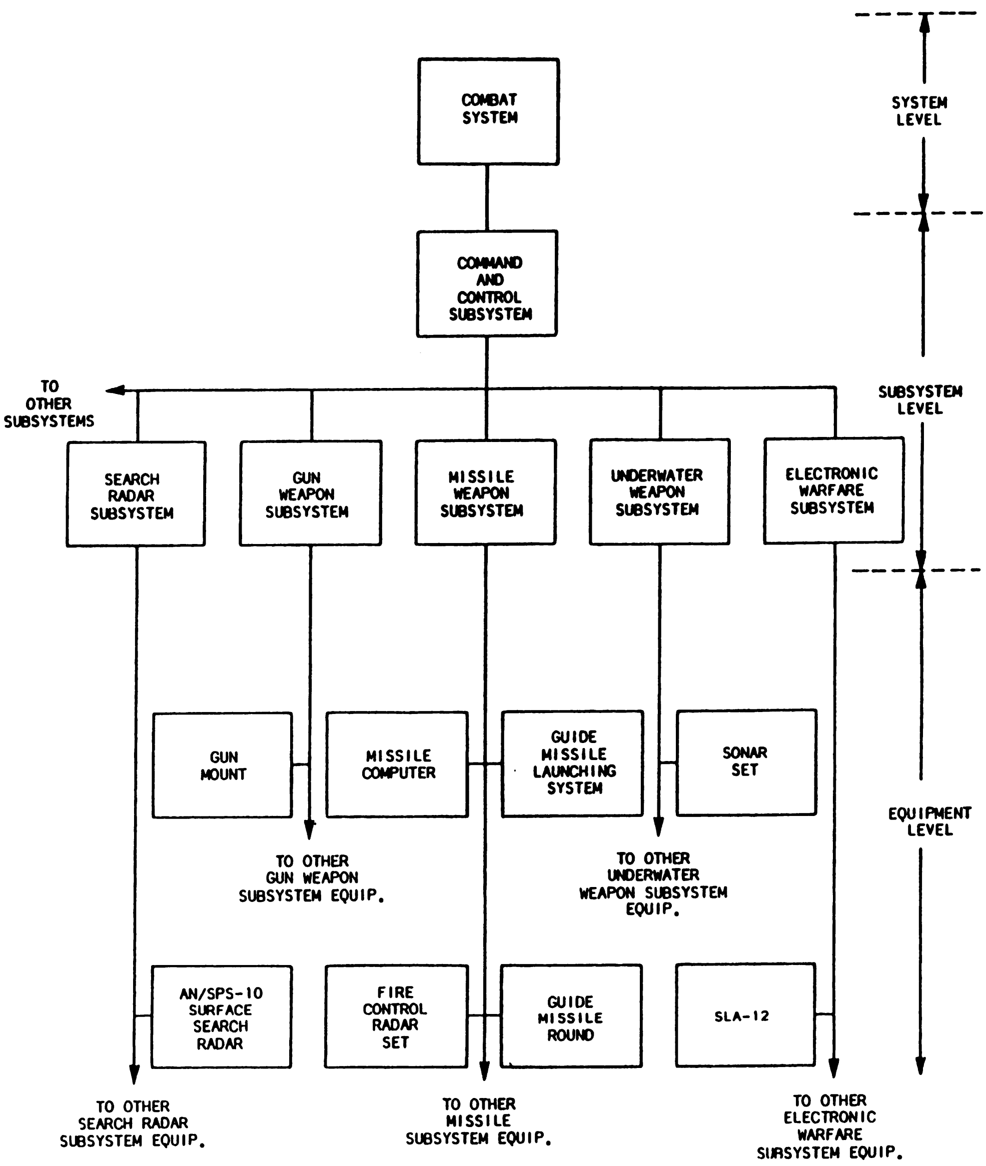

COMBAT SYSTEM
COMMAND AND CONTROL SUBSYSTEM
SYSTEM LEVEL
SUBSYSTEM LEVEL
EQUIPMENT LEVEL
TO OTHER SUBSYSTEMS
SEARCH RADAR SUBSYSTEM
GUN WEAPON SUBSYSTEM
MISSILE WEAPON SUBSYSTEM
UNDERWATER WEAPON SUBSYSTEM
ELECTRONIC WARFARE SUBSYSTEM
GUN MOUNT
MISSILE COMPUTER
GUIDE MISSILE LAUNCHING SYSTEM
SONAR SET
TO OTHER GUN WEAPON SUBSYSTEM EQUIP.
TO OTHER UNDERWATER WEAPON SUBSYSTEM EQUIP.
AN/SPS-10 SURFACE SEARCH RADAR
FIRE CONTROL RADAR SET
GUIDE MISSILE ROUND
SLA-12
TO OTHER SEARCH RADAR SUBSYSTEM EQUIP.
TO OTHER MISSILE SUBSYSTEM EQUIP.
TO OTHER ELECTRONIC WARFARE SUBSYSTEM EQUIP.

Figure 7-1.—Typical combat system hierarchy.

equipment as a subsystem or the fire control system (FCS) as a whole, on a daily basis. How many times have you said, "If I had a dollar for every time I've done this test ...". The DSOT procedures for all gun and fire control systems are covered by MRCs, so we'll lightly cover this test. The DSOT varies from system to ship class. As an example, let's consider the DSOT for the Mk 86 gunfire control system (DD-963 class). The DSOT for the Mk 86 system is an extensive test of the fire control system and the Mk 45 LWGM. This system generates and displays test surface targets on the plan position indicator (PPI) scope. Targets are acquired and tracked with one target

ANSWERS TO QUESTIONS Q1 AND Q2.

A1. Weekly.

A2. The Ship's Electronics Readiness Team (SERT).

for each tracking channel. This data is then checked and analyzed. Console control functions and data readouts are checked, which ensures that the interface between the control console and channel is correct.

This last part of the test checks the data transmission to and from your gun system. Gun train, elevation, and fuze orders are sent to the mount. When the mount goes to remote and matches the gun orders, feedback signals are sent back to the computer for evaluation.

The Mk 86 TV sighting system, B-scan displays, digital read-out displays, firing circuits, and so forth, are all tested daily.

INTERFACE TESTS

Interface tests serve to verify computer intercommunication between two or more digital systems in a combat system. The two interface tests we will discuss are the programmed operational functional appraisal (POFA) and the end-around test (EAT). Both tests provide a computer printout for test analysis. Although you are not directly involved in these tests, your system's accuracy depends on the data provided from these tests.

For a greater understanding of what these tests provide, it is recommended that you walk through one of these tests with your FC counterpart.

Programed Operational Functional Appraisal (POFA)

POFAs enable the technicians to verify intercomputer operational capabilities between the Navy Tactical Data Systems (NTDS) computer complex and the fire control computer. The test is run by a special computer program that is loaded into the NTDS computer. The POFA test is initiated from the NTDS computer complex.

End-Around Test (EAT)

This type of test uses the fire control switchboard to connect (or end-around) a computer output channel back to the computer on an input channel. This test compares the data out with the return data to provide a graph of the systems faults (if any are located). This will provide the Fire Controlman an isolation aid in keeping his fire control system operating at peak performance.

Q3. What system operability test is designed to test each individual subsystem?

Q4. What system operability test is used to check the intercommunication between the computer and two or more digital systems?

TEST RESULTS

After a test is conducted, the final condition of the system must be analyzed. Test results, in the form of dial readings, graphs, and printouts, will give the technician a basis from which he can conduct repairs and/or calibrations as deemed necessary. Unless you are able to interpret the test results, system readiness can be considered vague at the very best. As a Gunner's Mate First Class, your responsibility is to assist the Fire Controlman in further analyzing these tests to determine trends so that equipment discrepancies may be identified before it malfunctions.

Before 1938, the transmission and follow-up systems of guns and directors were tested only for alignment with all the units of the system at static. Realistically, you will rarely find a situation where the target and weapons platform are at rest. When tracking a target, the fire control system and gun system are both in motion. Therefore, it is necessary that the systems be aligned in static and that certain tests be verified with the system(s) in the dynamic mode. The ability of a gun system to follow the dynamic signal of a fire control system must be checked to verify accuracy. This test is called a dynamic accuracy test. A computer can be checked alone, or in combination with a gun or director system, or both. The resulting gun and fuze orders are then sent to an error recorder. At this point, the corrections can be made and a dynamic test run to verify accuracy. The tape made by the error recorder then becomes a permanent part of the history file of the system.

Q5. In what form are the test results of the End-Around Test provided to the technician?

SUMMARY

In this chapter you have been introduced to the level of maintenance required to maintain a fire control system as an integral part of a ship's combat system. The tests mainly associated with this level of maintenance are the overall combat system operability test (OCSOT), daily system operability test (DSOT), and Interface Tests. You should understand that the tests discussed in this chapter are primarily conducted by the Fire Controlman. As a Gunner's Mate (Guns) First Class, any deficiency discovered by the Fire Controlman will directly affect the efficiency of your equipment to engage and neutralize your target. You must understand what these tests are and how they may affect your system.

REFERENCES

Fire Controlman First Class, NAVEDTRA 10278, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1987.

ANSWERS TO QUESTIONS Q3 THROUGH Q5.

A3. The Daily System Operational Test (DSOT).

A4. The Interface Test.

A5. Dial readings, graphs, and printouts.

CHAPTER 8

BATTERY ALIGNMENT

Now that you have been exposed to the various types of tests to determine the accuracy and operability of fire control, it is imperative that you be able to align your system when faults are identified after initial alignment, or after faults have been corrected. Every subsystem must be aligned to those tolerances established by the manufacturer's design criteria, and the data provided by the shipyard upon completion of initial installation. What you will learn in this chapter is intended to assist you in understanding the principles of alignment. For a more detailed understanding of battery alignment, it is strongly recommended that you become more familiar with *Theory of Combat System Alignment*, SW225-AO-MMA-010/OP 762 ALIGN THEORY.

BASIC TERMS

Basic terms as applied to battery alignment are as follows:

EQUIPMENT: Any unit of a gun weapon system; gun, director, radar, etc.

EQUIPMENT ALIGNMENT: The internal alignment of components within an equipment.

OFFSET CENTERLINE: A line parallel to the ship's centerline.

REFERENCE EQUIPMENT: Equipment used as the reference when aligning other combat system equipment in train and elevation.

ROLLER PATH: Precision machined surface on which directors, gun, and missile systems rotate.

SUBSYSTEM: Two or more equipments which operate together.

SYSTEM ALIGNMENT: Equipment of a system aligned together or to a standard reference.

THEORY OF ALIGNMENT

As we learned in chapter 7, the combat systems aboard modern naval vessels are made up of various subsystems. For these subsystems to function at their optimum, each requires an exact exchange of information so that, when connected as a system, they function as designed.

To ensure that an exact exchange of data among the various related subsystems occurs, all gun bore axes, missile launchers, fire control directors, gyro compasses, and other related equipment should be parallel (when no other parallax or other ballistic corrections have been made). These pointing lines must remain parallel when in motion, within acceptable error tolerances.

Q1. *To achieve the maximum effectiveness of your gun system, what must be done?*

Q2. *To what publication should you refer for information pertaining to battery alignment?*

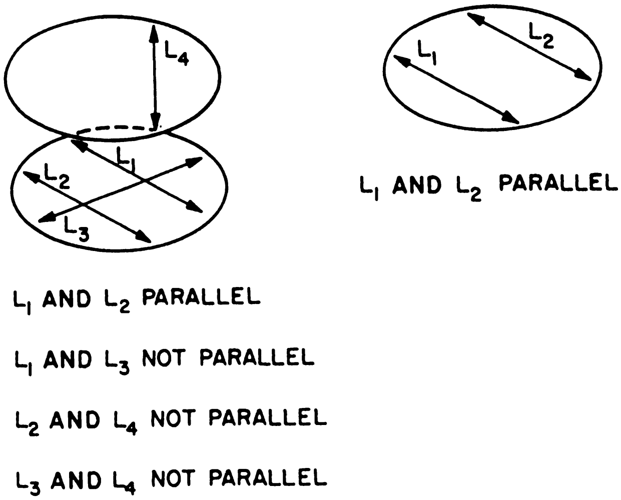
DEFINITION OF ALIGNMENT

Alignment is the procedure required to establish parallelism within acceptable error tolerances between combat systems components. These tolerances are established when a ship is first constructed, or at the time of a major shipyard overhaul of the gun or fire control system. When the alignment is complete, the gun or launcher has been aligned to the reference equipment. Depending upon the class of ship, this reference equipment could be a director or a radar. This reference equipment has been finely tuned with respect to the roller path it rides on and the offset centerline. System alignment of a ship's weapon system to a common reference point is battery alignment.

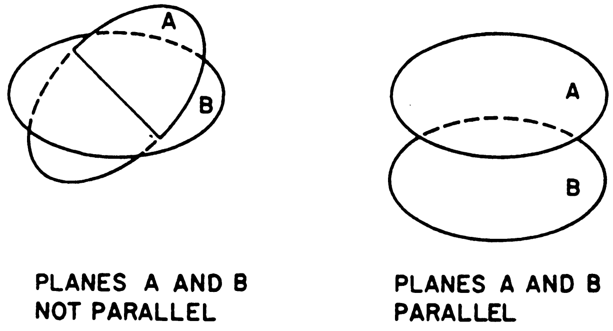
Alignment, when used in reference to a shipboard combat system, is the adjustments and orientation of components and subsystems. The idea behind the alignment is to ensure that all elements of the system point to the same point in space at the same time. The best and simplest example of this would be to set the cross hairs of your high power rifle scope on the center of a target and adjust it until you can hit dead on the bull's eye consistently.

Alignment is based on the concepts of parallel lines, parallel planes, and a geometric coordinate system. Parallel lines, shown in figure 8-1, view A, are defined as two lines in the same plane that do not intersect. Parallel planes, shown in figure 8-1, view B, are defined as planes that do not intersect. A geometric coordinate system provides a method to determine the position of a point, line, curve, or plane in a space of given dimensions or a reference frame. An example of a geometric coordinate system is the spherical coordinate system where the center, or reference point, is used to determine angles in train and elevation along the radius of the sphere (as shown in figure 8-2). This system is the basis for alignment in fire control and gunnery.

Ultimately, the alignment of pointing lines, planes, and coordinate systems is used to establish a pointing line for each piece of equipment in the subsystem (fig. 8-3). Once the reference point is selected, a reference direction is established from which angles can be measured. Angles are measured about the reference point, beginning from the reference direction.


L_4
L_1
L_2
L_3
L_1
L_2
L_1 AND L_2 PARALLEL
L_1 AND L_2 PARALLEL
L_1 AND L_3 NOT PARALLEL
L_2 AND L_4 NOT PARALLEL
L_3 AND L_4 NOT PARALLEL

A. PARALLEL LINES



B. PARALLEL PLANES

Figure 8-1.—A. Parallel lines; B. Parallel planes.

Reference Frame

The reference point, reference direction, and reference plane combined, form the reference frame. In this frame we derive the train and elevation angles measured about a reference point.

ANSWERS TO QUESTIONS Q1 AND Q2.

A1. It must be aligned to the manufacturer's design criteria.

A2. Theory of Combat System Alignment Theory, SW225-AO-MMA-010/OP 762 ALIGN THEORY.

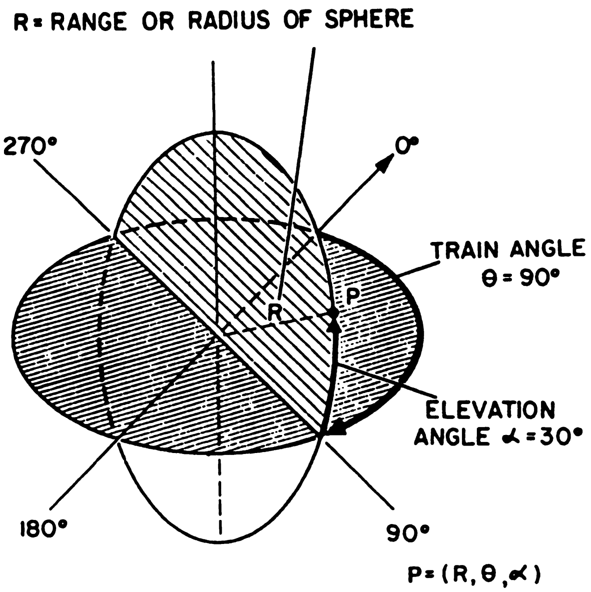


Figure 8-2.—Spherical coordinate system.

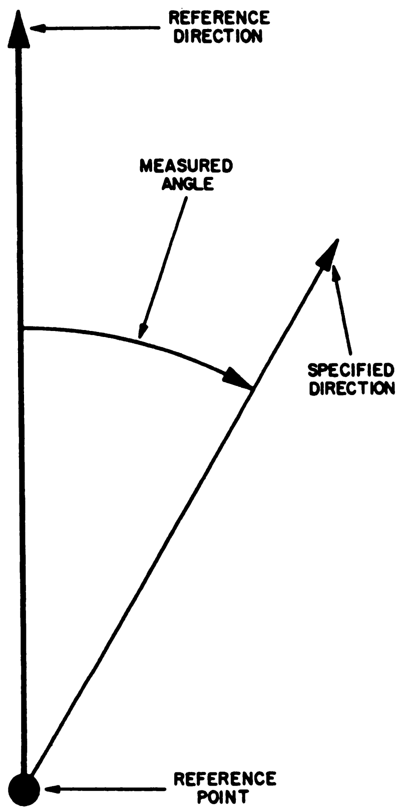
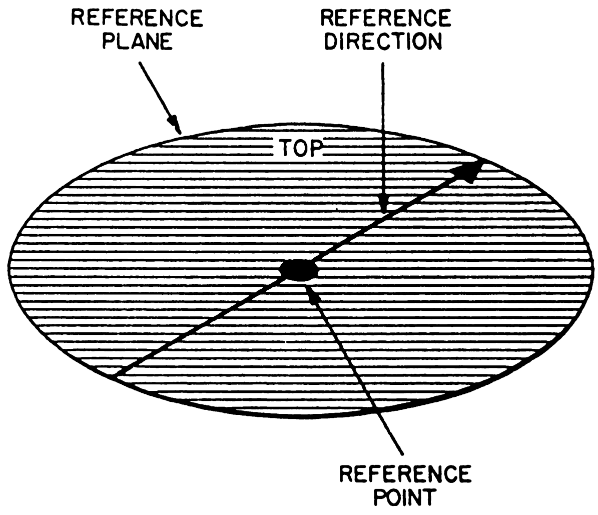


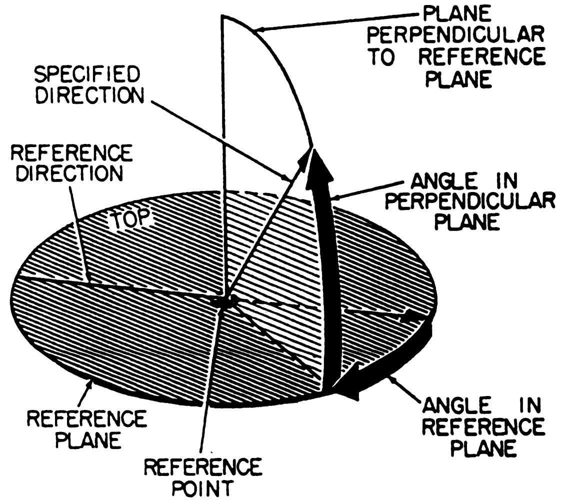
Figure 8-3.—Measured angle of reference direction.

Complete Reference Frame

During initial ship construction, the master reference plane (MRP) is established and acts as a reference for the foundation machining and roller path inclination reference during ship construction. After construction, the weapon control reference plane serves as a reference for future alignments. The MRP is not used for post-construction alignment unless major damage occurs to the ship. This typical reference plane, as shown in figure 8-4, view A, is referred to as



A. TYPICAL REFERENCE FRAME



B. COMPLETE REFERENCE FRAME

Figure 8-4.—Weapons control reference frames.

the reference plane and is developed during ship construction. Elevation angles are measured in a plane perpendicular to the reference plane to form the complete reference frame, as shown in figure 8-4, view B. For more detailed information on alignment definition, study *Theory of Combat System Alignment,* SW225-AO-MMA-010/OP 762 ALIGN THEORY, chapter 2, sections 2-1 and 2-2.

Q3. What constitutes battery alignment?

Q4. Alignment is based upon what three concepts?

Q5. What three references constitute the reference frame?

ALIGNMENT RESPONSIBILITIES

During initial construction or modernization, shipboard alignment is normally conducted by shipyard personnel and, at times, by Mobile Technical Units. Shipyards conduct only initial alignment work, but can complete the following checks:

1. Alignment after repair work and equipment adjustments that are clearly outside the capabilities of ships force.
2. Equipment alignment of new or refurbished equipment, or equipment that has had its supporting structure modified.
3. Checks to ensure that references such as benchmarks and tram blocks are properly installed.

Even though the ultimate responsibility for alignment falls on the commanding officer, it is your responsibility to monitor what is done, know what is done, why it is done, and most importantly, to ensure that it is done properly. Keep your chain of command informed as to the status of such equipment alignment. Alignments completed by a shipyard must, at best, be considered as a preliminary alignment, at least until such time that a certification can be accomplished on the gun and fire control equipment. Shipyard personnel initially install equipment using precision methods in a newly constructed ship. They take into account stress caused by operational loading, and adjust for accurate alignment when the ship is waterborne and contains 90 percent of the total load. When alignment procedures are undertaken thereafter, the ship should contain 80 percent total load of fuel, water, armament, and stores, distributed normally. The greater part of the work will consist of checks and small adjustments, unless the equipment has been damaged or moved out of alignment.

ALIGNMENT EQUIPMENT

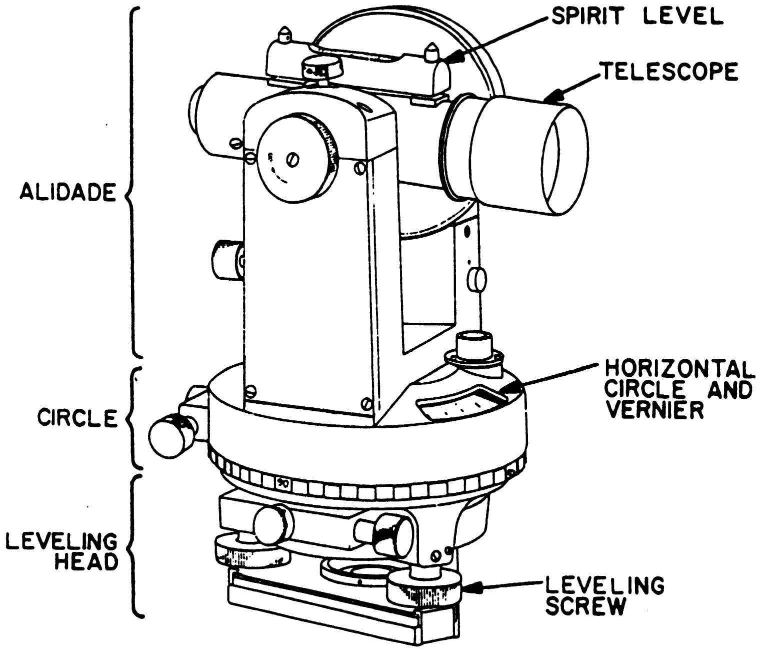
Once your equipment has been installed, you must adjust and align all your system components to the reference plane. To do this, various alignment instruments or devices have been developed. We will briefly discuss instruments used by the shipyard to conduct **initial alignment**. These are the transits, theodolites, clinometers, levels, and the Analog Inclination Data System (AIDS). Equipment used by ship's force personnel to **check the initial alignment** include optical alignment instruments, tram bars, and the gunner's quadrant. For more detailed information on any of these, you should refer to the manufacturer's handbook on the given instrument(s).

Transits and Theodolites

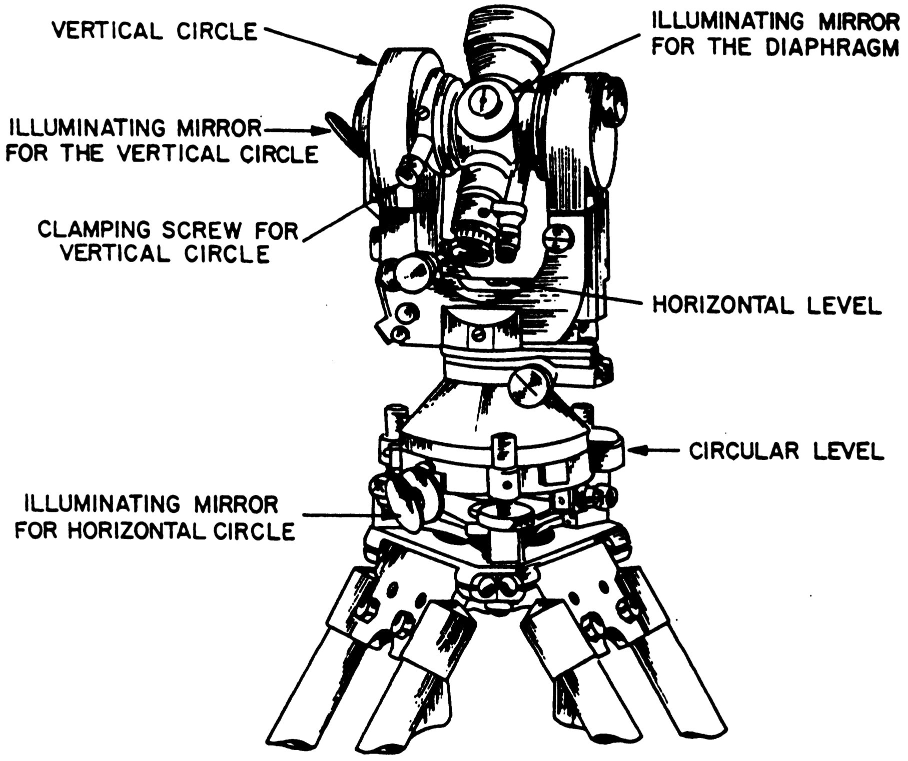
Transits and theodolites are used by the installing activity for establishing train and elevation zero and establishing reference lines for use during combat systems alignment.

The transit is an optical surveying instrument used to measure angles (fig. 8-5, view A). Simply, the transit provides an optical line of sight (LOS) that is perpendicular to, and supported on, a horizontal axis. The horizontal axis is perpendicular to a vertical axis about which it can rotate. The LOS of a transit is an optical telescope mounted on two rotational axes—horizontal and vertical.

The theodolite is similar to the transit, but is more accurate (fig. 8-5, view B). Theodolites employ micrometer microscopes which are designed for rapid and accurate readings. They are used to read the graduated vertical (for elevation) and horizontal (for train) circles. Different types of theodolites can be read directly



A. A TYPICAL TRANSIT


VERTICAL CIRCLE
ILLUMINATING MIRROR FOR THE DIAPHRAGM
ILLUMINATING MIRROR FOR THE VERTICAL CIRCLE
CLAMPING SCREW FOR VERTICAL CIRCLE
HORIZONTAL LEVEL
CIRCULAR LEVEL
ILLUMINATING MIRROR FOR HORIZONTAL CIRCLE

B. A TYPICAL THEODOLITE

Figure 8-5.—A. A typical transit system; B. A typical theodolite.

to 10", 1", or 0.1" of arc. Certain circumstances will dictate what type of alignment equipment will be used.

Q6. As a minimum, to what percentage of total load must the ship be loaded for a check of preliminary alignment underway?

Q7. What optical tool is designed to check optical line of sight to within 0.1" of arc?

Clinometers

The clinometer is an instrument used for measuring inclination in a horizontal plane. This is the information used to establish roller path data. Clinometers are principally used by shipyards to measure inclinations in equipment foundations and to determine equipment roller path inclinations (RPI). The two most common clinometers are shown in figure 8-6.

The Hilger and Watts TB95 is a microptic precision clinometer and has an optically viewed graduated glass circular scale, which is direct reading to one arc second. Symmetry is used in setting the scale for a reading.

The Warren Knight micrometer (drum type) is the most common device used when taking accurate roller path inclination measurements. This micrometer drum 90-degree clinometer is read directly to 1′ and can be interpolated to within 15" on the drum. The 6-inch base length makes this type of clinometer suitable for many uses. An adjustable base permits reading angles from zero, even when working surfaces are not perfectly horizontal.

When preparing to use a clinometer, ensure that the surface is clean and smooth. The clinometer should be clamped or sealed to the mounting surface. Care should be taken not to clamp it so tight that the clinometer becomes distorted.

Levels

The three principal types of levels are those which indicate entirely by means of graduations on the level vial, and adjustable levels which are hinged at one end and provided with calibrated micrometer adjustments at the other end to extend the range beyond that of the level vial alone. Figure 8-7 shows the three most common levels in our inventory.

The Hilger and Watts TB4 is an 8-inch adjustable block level calibrated to measure the smallest of tilts. It was designed with flat and vee reference faces to allow use on flat and cylindrical surfaces. A small bubble level has been built in to allow for rough leveling perpendicular to the main level direction. The micrometer can be interpolated to within 15 arc seconds.

The Huet adjustable optical level is a coincidence type level, calibrated to read a minute angular tilt. A split level bubble prism reader is built in for accurate level determination. Like the TB4, this level also has the pre-reference bubble and a vee reference for use on cylindrical objects. The micrometer adjustments are in hundred-thousandth of an inch with one division equalling two seconds of arc.

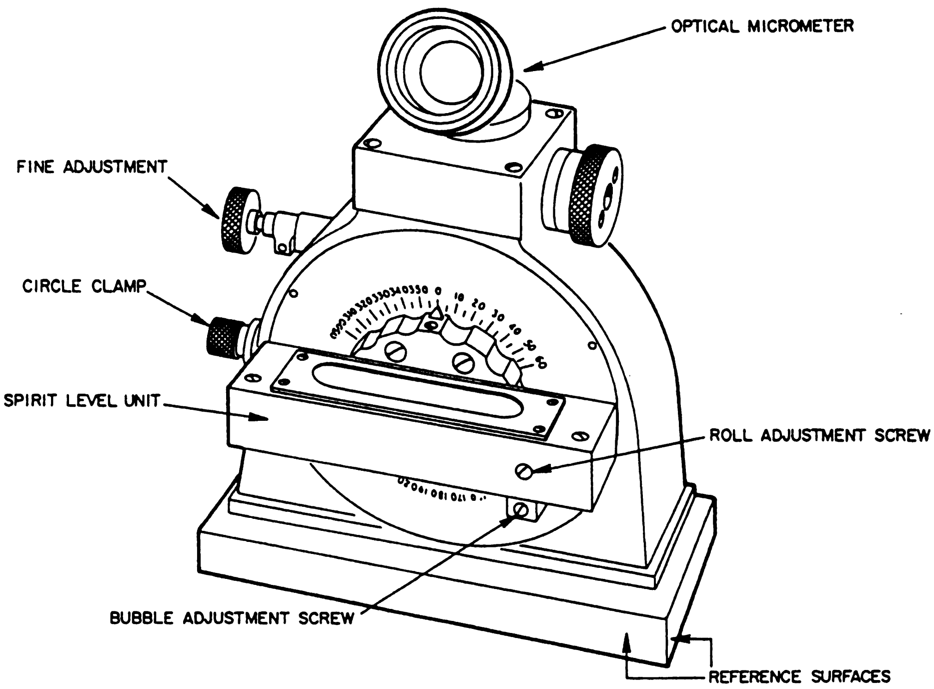
The Sine-bar type level uses a screw to raise and lower one end of the bar on which a spirit level is fixed. A dial mounted on the screw, and a scale attached to the spirit level, are used to read the inclination of the base. Care and mounting procedures duplicate those of the clinometer.

ANSWERS TO QUESTIONS Q3 THROUGH Q5.

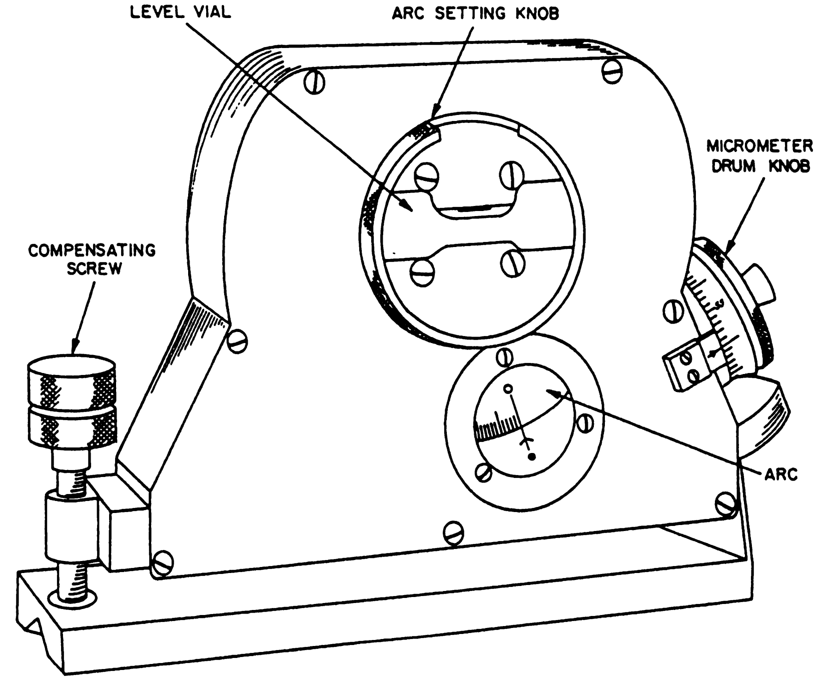
A3. Battery alignment is the alignment of a ship's weapon system to a common reference point.

A4. Parallel lines, parallel planes, and a geometric coordinate system.

A5. Reference point, reference direction, and reference plane.

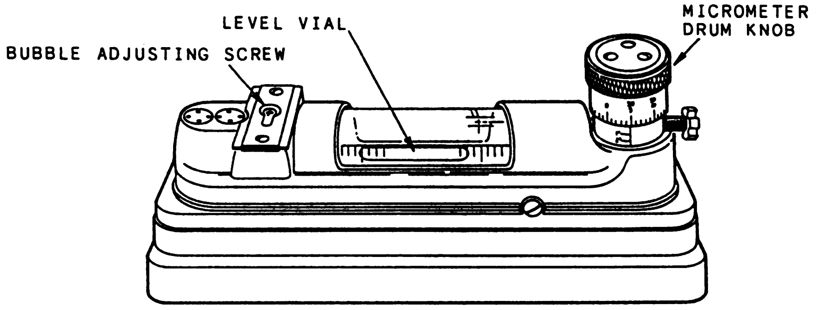


A. HILGER AND WATTS TYPE TB95 CLINOMETER

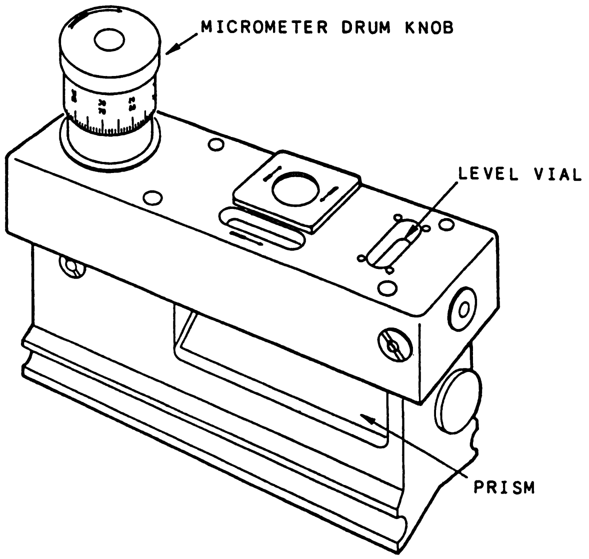


B. WARREN KNIGHT MICROMETER DRUM TYPE CLINOMETER

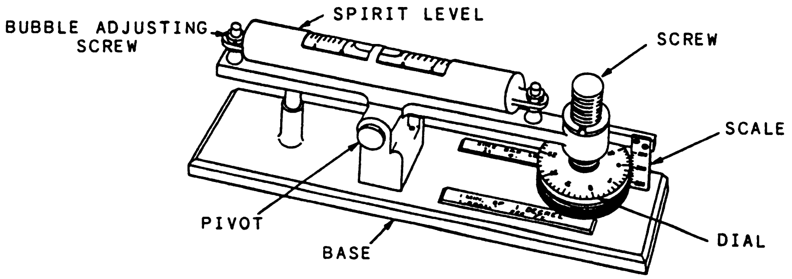
Figure 8-6.—Clinometers.



A. HILGER AND WATTS TYPE TB4 LEVEL



B. HUET ADJUSTABLE OPTICAL LEVEL



C. SINE BAR TYPE LEVEL

Figure 8-7.—Levels.

ANSWERS TO QUESTIONS Q6 AND Q7.

A6. 90%.

A7. The theodolite.

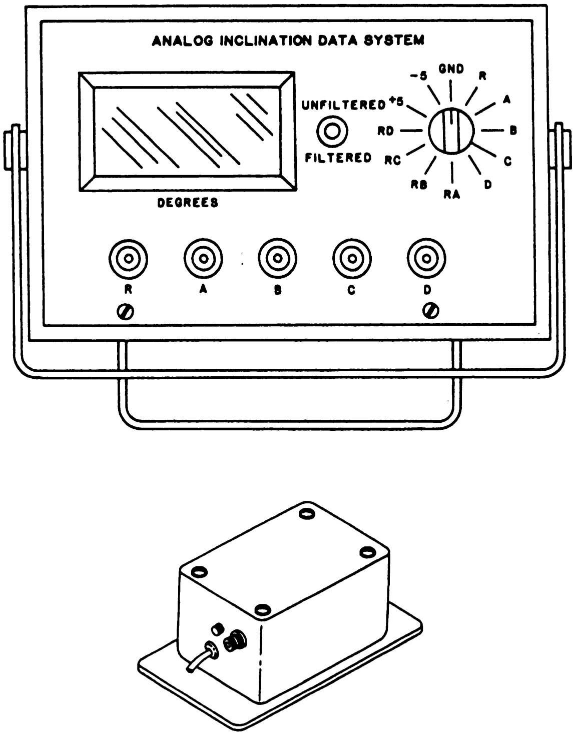


Figure 8-8.—Analog Inclination Data System (AIDS).

Analog Inclination Data System (AIDS)

The Analog Inclination Data System (AIDS) (fig. 8-8) is a device used for taking RPI during combat systems alignment. It is a very sensitive, specialized, servo-accelerometer (sensor) and signal conditioning electronics package. AIDS is capable of sensing very small angular displacements. When the sensor is level, its axis is parallel to the force of gravity. Therefore, the output is zero or null. Tilting the device will cause a negative or positive output (depending on the direction of tilt).

Optical Alignment Instruments

An optical alignment instrument is an optical device used to establish the pointing line of equipment. The pointing line could be a gun bore axis, as shown in figure 8-9, or the center line of a torpedo tube. Accurate alignment is not possible unless the pointing line is accurately determined.

The most commonly used optical alignment instrument that Gunner's Mates use is the boresight telescope. This instrument, when installed properly (see manufacturer's instruction for installation), will represent the gun bore axis. This enables us to align the local surface operators gun telescope of a telescope in the Mk 42 Mod 9/10, 5"/54 cal. with its gun bore center of axis.

Tram Bars

One method for resetting a rotating portion of a gun mount with respect to its stationary structure is through the use of a tram bar. This tram bar, when adjusted properly, represents a known distance between two points. One point

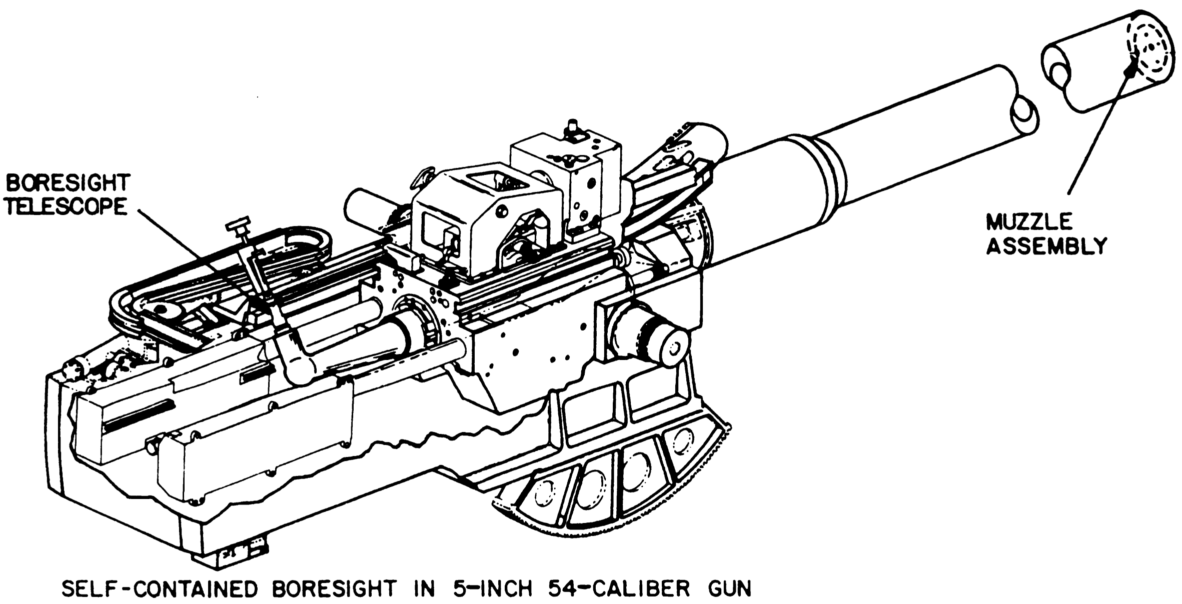


Figure 8-9.—Optical alignment.

can be located on the fixed structure of the mount; the other will be located on the rotating portion of the mount. These points are thus called tram blocks (see figure 8-10 for illustrations of tram bars and tram blocks). The tram bar is part of your special tools issue and the basic procedures for tramming are covered in *GMG 3 & 2*, NAVEDTRA 10185.

The use of the tram bar and blocks is a simple evolution. As a refresher, all you must do is train the mount to a pre-recorded position, position the tram bar on the tram blocks, and move the mount to align the tram bar scribe marks (fig. 8-11). Once the new reading is recorded, compare this new data to that which was recorded in your log. (Although drydock alignment is preliminary, tram readings should be taken and recorded after zero mount train has been established and the dials set). If, in the event the readings are not the same as previously recorded, dial corrections can be made at this time. Follow your technical manuals' instructions for adjustments. Extreme care must be used when handling and using the tram bar. Although it is made of a rugged material, it is still a calibration tool and should be treated with the same respect.

Gunner's Quadrant Mk 7

Roller path data is taken with a gunner's quadrant. The Mk 7 gunner's quadrant is the type currently in use (fig. 8-12). A gunner's quadrant

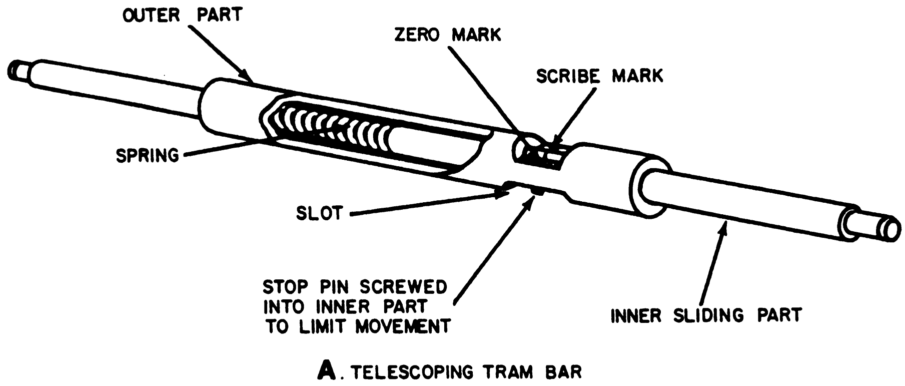


Figure 8-10.—Tram bar and tram blocks.

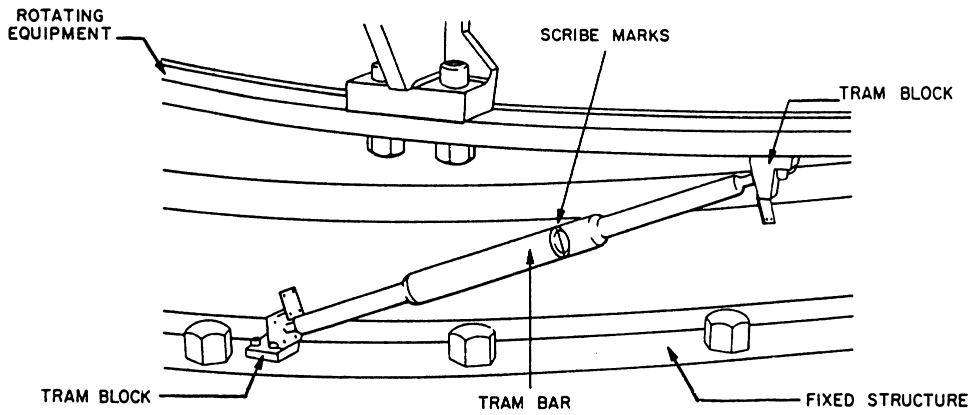
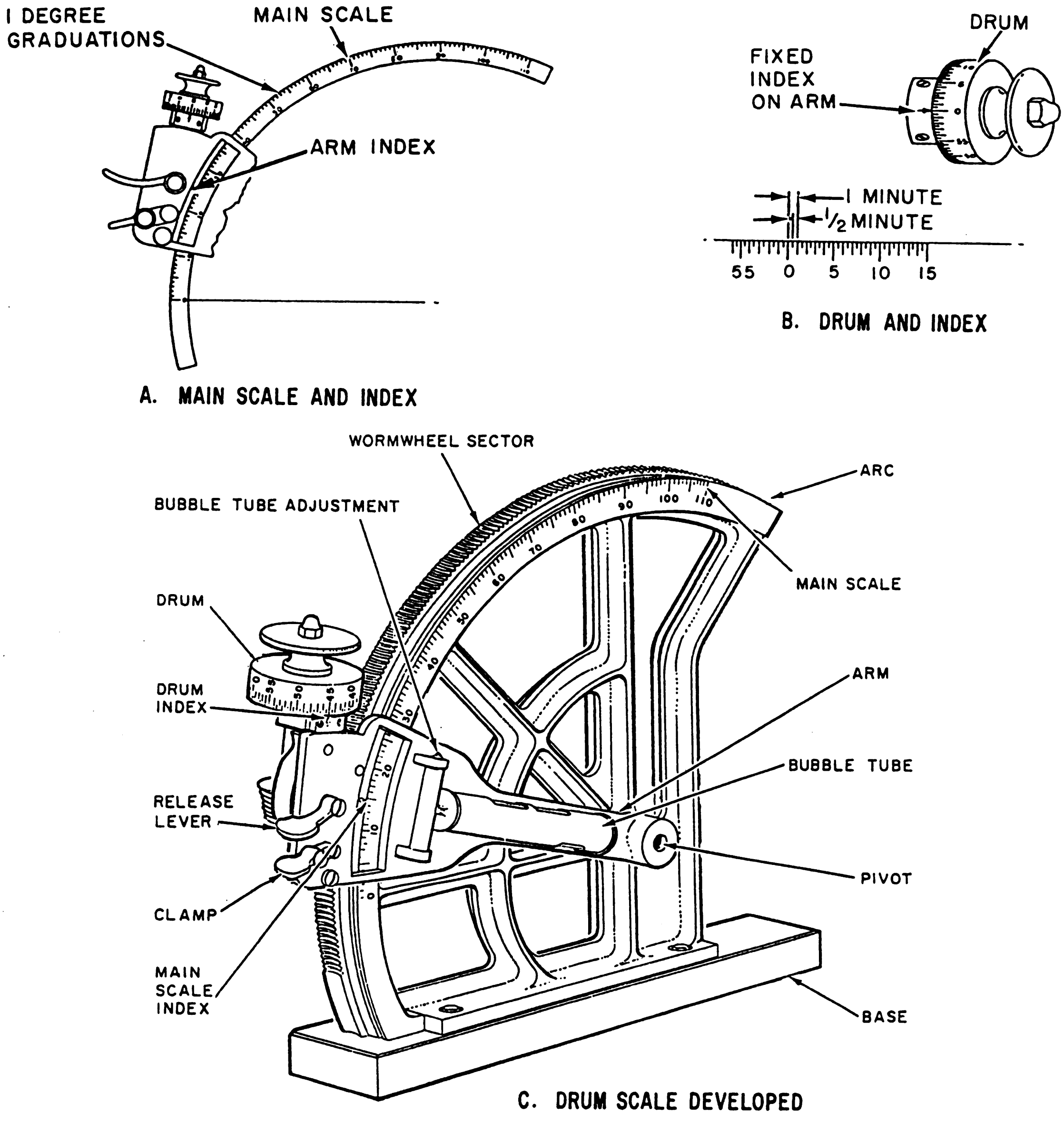


Figure 8-11.—Tram bar, tram blocks, and scribe marks.



53.122

Figure 8-12.—Mk 7 gunner's quadrant (drum type).

is similar to a carpenter's level, but is more accurate. It is provided with an arc for measuring the angle of inclination. The inclination is read from a micrometer drum mounted on the shaft of the tangent screw.

To measure an element's inclination from true horizontal, follow these steps:

1. Secure the equipment to some smooth surface on the gun so that the line of the quadrant is parallel to the axis of the gun bore and the pivot of its arm is forward.

2. Elevate the element or shim the quadrant up in front to some convenient angle. This will make all readings positive and eliminate working with both plus and minus readings.

3. Train the gun to 0 degrees, level the bubble, and read the quadrant. Repeat this procedure at 30 degree intervals of train until the element has been trained 360 degrees or has reached the train limit. For elements limited to smaller sectors, or where greater ease in plotting and fairing the data curve is desired, train intervals of 10 to 15 degrees may be used. For each train interval, record the quadrant reading opposite the train dial reading.

A set of typical roller path data is shown in table 8-1. Note that all readings are positive; the quadrant was slightly elevated to avoid negative numbers. If the roller path is plotted on a graph, the resulting curve will show the magnitude of the tilt above or below the true horizontal at any bearing.

Table 8-1.—Typical Roller Path Data

TRAIN ANGLE (BEARING)	INCLINATION FROM HORIZONTAL
0°	2° 30′
30°	2° 40′
60°	2° 47′
90°	2° 50′
120°	2° 47′
150°	2° 40′
180°	2° 30′
210°	2° 20′
240°	2° 13′
270°	2° 10′
300°	2° 13′
330°	2° 20′
360° (0°)	2° 30′

Q8. What two shipyard instruments are used to measure inclination in a horizontal plane?

ALIGNMENT PROCEDURES

Whether you are conducting an alignment at sea or in drydock, the basic principles of alignment are the same. You must conduct the final alignment of your ship at 90 percent total load, actual or simulated, using ballast. The procedures for conducting drydock alignment are found in SW225-AO-MMA-010, *Theory of Combat System Alignment*.

Sequence of Alignment

Several major steps in aligning your combat system must be accomplished in a specified sequence. These steps are performed assuming that all the internal subsystems alignments are accurate and complete. Verification of these alignments are a must and should not be assumed at any cost. The detailed sequence of alignment is found in SW225-AO-MMA-010/OP 762 ALIGN THEORY, chapters 4 and 5, appendix A through D. Nevertheless, the sequence of alignment is as follows:

1. Establishment of the reference planes
2. Establishment of the reference marks
3. Establishment of parallelism
4. Performance of fire control radar frequency (RF)—optical control alignment
5. Performance of train and elevation alignment
6. Establishment of benchmark and tram reference readings

As a Gunner's Mate , your concern will start at major step 5.

Performance of Train and Elevation Alignment

Train and elevation alignment is performed by fleet and fleet support personnel to ensure that we can hit what we are firing at. Two methods are currently in use. First is the theodolite method for establishing train and elevation zero; the second is the star check method to receive train and elevation space alignment. These procedures are accomplished pierside under ideal conditions.

THE THEODOLITE METHOD.—In the first method, train zero is defined as that angle at which the pointing line of an equipment is parallel to the centerline reference plane. Elevation zero is that angle at which the pointing line of an equipment is parallel to its own roller path plane. This train and elevation zero is determined by mutually boresighting the theodolite and equipment telescopes—then zeroing the equipment position data dials and data transmission synchros. You must do this procedure with the parallax dials and RPI compensators set to ZERO. The error of measure must, upon completion, be less than one arc minute.

After train and elevation zeroes have been established, the parallax correction, bearing of the high point (BHP) and inclination of the high point (IHP), are entered into their respective correction devices. Once these values are entered, the train and elevation zero of all equipment pointing lines should be parallel.

THE STAR CHECK METHOD.—The star check method is not only used by fleet support personnel to align combat systems equipment; it is also a means that can be used by fleet support and fleet personnel to verify train and elevation alignment. The star check method is used for conducting train and elevation alignment between the alignment reference and other equipment to be boresighted. If applicable, the BHP and the amount of inclination of the roller path high point are entered into the equipment being aligned. The alignment, or alignment verification, is accomplished by comparing the equipment position with the position of the alignment reference when their optical axes are made parallel by sighting on a celestial body.

With the average train and elevation errors now determined, and the train and elevation dials adjusted to correct the errors, the alignment equipment is then positioned to the indicated train and elevation zero position. The train and elevation position data transmission synchros are electrically zeroed.

Benchmark and Tram Reference Readings

It is necessary to have reference readings because the equipment position data dials may become misaligned as a result of vibration, normal wear, or a maintenance action. Reference readings should be established upon completion of any alignment. The alignment verification obtained by using a benchmark will be accurate only if the angle between the reference line and the position of the pointing line established by the benchmark does not change as a result of hull distortion or some other cause. Figure 8-13 illustrates how the benchmark has been offset by the distortion of the hull.

Equipment alignment should not be made using a single benchmark check. Several checks should be made to establish the amount of error to correct. The use of a tram bar and tram blocks further establishes the amount of error to correct. When a constant change of error is noted in the benchmark checks, and no change is noted in the tram bar checks, it is a good indication of how much hull distortion has occurred. In short, the benchmark checks establish the ship's centerline to the reference director where all alignment data is established. When you compare the tram readings from a particular gun system (which is not affected by hull distortion), to that of the benchmark, it is possible to plot the shifting of the hull, and to determine where the misalignment originates.

When alignment problems develop between the director and the gun system, it is necessary to establish where the misalignment occurred. The use of the tram bar to check mechanical and electrical internal alignment is the quickest and easiest method. The last thing the Gunner's Mate and the Fire Controlman need to do is get involved with a multitude of benchmark checks to determine the amount of error to be corrected. A simple check of the tram readings will more than likely lead you to the required adjustment of a dial or synchro at the worst. Any casualty beyond this will have to be referred to your type commander for an external assist.

Q9. What is the first step of the alignment sequence?

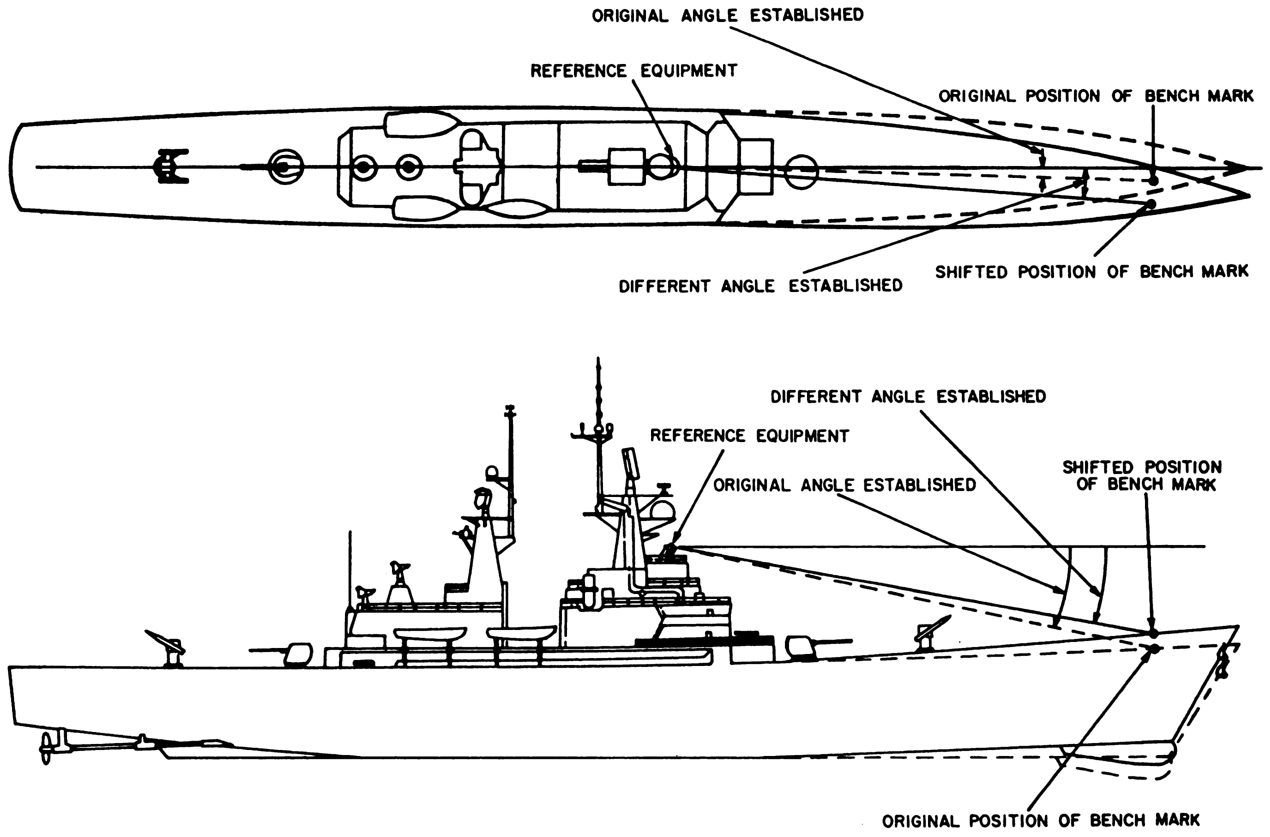

ORIGINAL ANGLE ESTABLISHED
REFERENCE EQUIPMENT
ORIGINAL POSITION OF BENCH MARK
DIFFERENT ANGLE ESTABLISHED
SHIFTED POSITION OF BENCH MARK
DIFFERENT ANGLE ESTABLISHED
REFERENCE EQUIPMENT
SHIFTED POSITION OF BENCH MARK
ORIGINAL ANGLE ESTABLISHED
ORIGINAL POSITION OF BENCH MARK

Figure 8-13.—Hull distortion.

Q10. At what major step in the alignment sequence does the Gunner's Mate become actively involved?

SUMMARY

As you have read and seen in this chapter on battery alignment, these procedures can become quite detailed to say the least. It is imperative that you, as a GMG1, take the time to read and further understand the workings of the procedures we have discussed. Make the best of every opportunity to observe the use of alignment tools and procedures. SW225-AO-MMA-010/OP 762 ALIGN THEORY is an excellent source of information, and should be used to answer any further questions you may have pertaining to combat systems alignment.

REFERENCES

Theory of Combat System Alignment, SW225-AO-MMA-010/OP 762 ALIGN THEORY, Commander Naval Sea Systems Command (Code 05L3), Washington, D.C. 20362, 1985.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

ANSWERS TO QUESTIONS Q8 THROUGH Q10.

A8. The clinometer and theodolite.

A9. The establishment of reference planes.

A10. Step 5. Performance of train and elevation alignment.

CHAPTER 9

TEST EQUIPMENT

Because of the increasing use of technology in our equipment, we must continue to learn more about electronics and its application to our systems. It is simple enough to say, "I can always CASREP and send for a MOTU assist," but that doesn't help you when that assist isn't available. As a leading Gunner's Mate, and possibly the senior gunner on your ship, it will be up to you to make those needed repairs to servo amplifiers, electro-hydraulic controlled servo valves, and related equipment. It is you who must teach that A school graduate and that deck seaman striker what they need to know.

To perform these tasks, you must have a complete working knowledge of your equipment and how it operates. You must also tailor a maintenance program to meet your equipment needs with respect to required maintenance. When a casualty occurs, it should become the norm for anyone of your technicians to grab whatever test equipment is available and commence troubleshooting procedures. These troubleshooting aids include test equipment, wiring diagrams, schematics, and systems maintenance publications.

To further assist you in your ability to troubleshoot a system malfunction, various courses are available through your local Mobile Technical Unit (MOTU). These are located throughout the world at most major naval installations. Some of these courses are General Purpose Electronic Test Equipment (GPETE) and Basic Soldering Techniques. On-the-job training (OJT) can also be conducted underway. The proper operation and knowledge of test equipment must become one of your skills so that you can be an effective GMG1.

Some of the newer systems we have in the fleet, such as the Mk 45 Mod 1, have automatic test equipment built right into the system to help you locate casualties. This equipment must be maintained—it will be your job to ensure it is kept in top operating condition at all times. Test equipments are the tools of your trade. You must learn how to use these tools to check, maintain, and repair the equipment assigned to you.

Ordnance test equipment includes various electrical, electronic, hydraulic, and mechanical test sets, meters, and measuring instruments, designed and constructed to perform tests of one or more specific types. Test equipment can be classified roughly as being either general-purpose or special-purpose.

General-purpose test equipment is used in performing a specific type or types of tests on a variety of ordnance equipment or systems. Some examples of general-purpose test equipment are multimeters, tube testers, oscilloscopes, oscillographs, signal generators, and hydraulic test kits.

Special-purpose test equipment is used in performing a specific type or types of tests on a specific type of ordnance equipment or systems. Some examples of special-purpose test equipment are the 5"/54 dummy fuze test gage, battery alignment test equipment, and the maintenance assist modules that are supplied with the 3"/50 cal. amplifier Mk 172 Mod 0.

The purpose of this chapter is to familiarize you with the use of general- and special-purpose test equipment. We will review some of the safety precautions you should take when working with test equipment, and we will describe the types and purposes of weapon systems tests conducted during maintenance, installation, troubleshooting, and planned testing.

Most of the general-purpose test equipment used with ordnance equipment is explained in the *GMG 3 & 2* training manuals. Also explained in the *GMG 3 & 2* manuals are the many maintenance groundwork procedures that help keep a weapon system in the fight during action. Before reading further, you should review the material on maintenance and test equipment in the *GMG 3 & 2* manual. In this manual we provide a general review of some of the maintenance and test equipment subject matter covered in *GMG 3 & 2*.

Q1. What are the two classes of test equipment?

Q2. What rate training manual gives you the background needed to understand basic test equipments?

MAINTENANCE

Maintenance of ordnance equipment falls into four basic categories: electrical, electronic, hydraulic, and mechanical. These maintenance categories make up a system's maintenance program that falls into two main classes—preventive (routine) and corrective (special).

ROUTINE MAINTENANCE

Most of our daily schedule is comprised of routine preventive maintenance. This type of maintenance program includes the thorough, daily transmission checks (discussed in chapter 7). Potential casualties discovered here are usually in an early stage, and correcting them is a simple evolution. In most cases, repair requires only minimum knowledge; you will only need to follow the technical manual for the system.

The casualties you find in electrical or electronic equipment can be caused by any number of reasons. Some casualty indicators include, but are not limited to: blown fuzes, wear and tear, pitted contacts in switches and, most frequently, corrosion of some sort. These casualties can be easily prevented if you have a bit more than average knowledge of electricity and can correct them during normal PMS.

Moisture is a major problem and most noteworthy of mention. This casualty can be found in most topside areas. A prime example of a moisture casualty can be found on the 3"/50 cal. open mount. You have various switches positioned throughout the loader and insulated by heat shrink tubing. Under the right conditions, saltwater and other contaminants can easily penetrate these insulators, shorting or grounding the switch, giving you false indications and sending you on a 3- or 4-day casualty analysis frenzy. You learn the true meaning of frustration quickly, unless you can read an electrical schematic diagram and have the knowledge to isolate symptoms. This frustration can be eliminated by a casual periodic inspection to ensure that all sealing surfaces are in good repair.

For the most part, the procedures for correcting most any casualty you will run across, such as electrical adjustments, are found in your equipments OPs. However, before you make any adjustments to your equipment, you should assure yourself that the casualty is due to a faulty adjustment.

During preventive (routine) maintenance, you conduct periodic checks and inspections of your equipment, and make minor repairs, correcting the obvious discrepancies and potential malfunctions.

CORRECTIVE MAINTENANCE

Corrective maintenance is required when casualties occur (in spite of a good preventive maintenance program), and are of such a nature that they are not easily located or repaired.

Q3. What are the four basic categories of maintenance?

Q4. What are the two classes of maintenance?

Q5. What is the most common cause of casualties in ordnance equipment located topside?

Q6. Before making any adjustments to your equipment, what should you first verify?

TEST INSTRUMENTS

When studying for advancement to GMG 3 & 2, you studied the use of electrical measuring instruments (meters). To maintain ordnance equipment, you must have a good working knowledge of meters, tube testers, and other instruments. As a first class, you must become more proficient with these aids. We will review some meters commonly found in ordnance systems, along with a brief description of their functions.

VOLTMETER

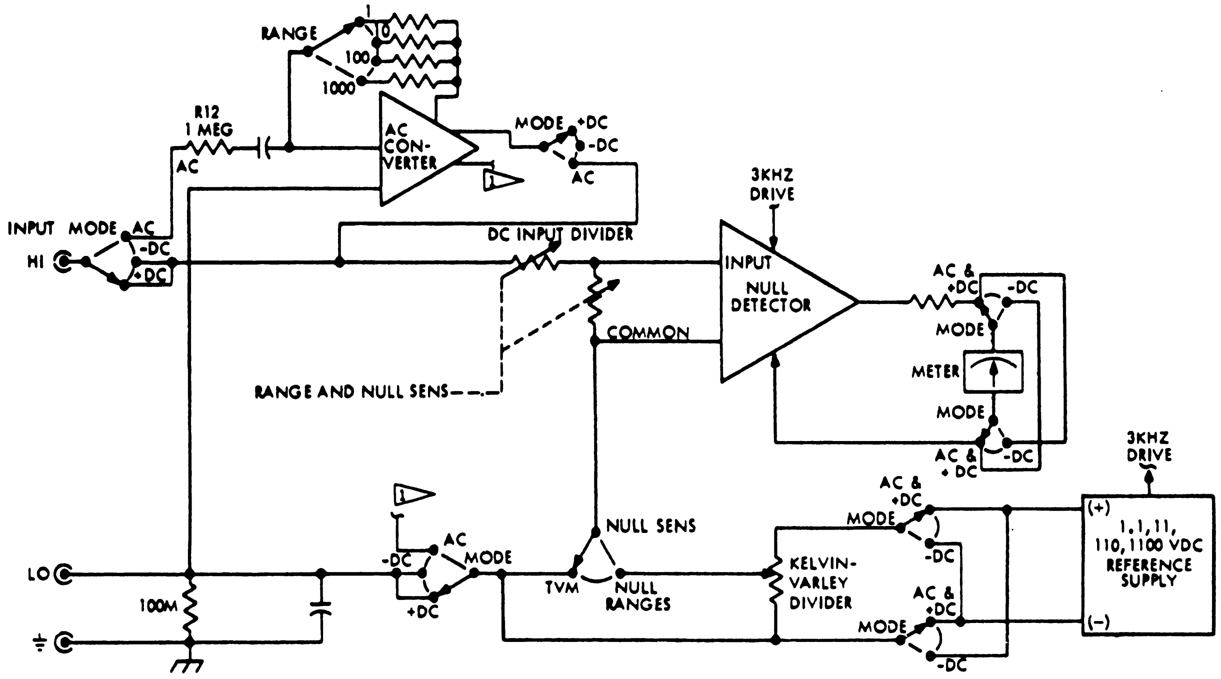
The voltmeter measures voltage (also called potential difference, EMF [electromotive force], or voltage drop). It uses the basic meter movement by placing it in series with a high resistance. The range of the voltmeter is extended by incorporating several fixed resistors. A schematic of a multi-range voltmeter circuit is shown in figure 9-1.

You can select the desired scale by turning a selector switch. To protect the meter, you should always use the highest scale to begin a voltage test. Strange things have happened to cause a 5-vdc circuit to read 40+ volts. The meter can be scaled down to achieve a mid-scale reading. The sensitivity of a voltmeter determines how accurately it can measure the voltage in a circuit. Sensitivity is usually indicated on the face of the meter in ohms-per-volt. Total meter resistance can be determined by multiplying the scale setting by the meter sensitivity. For example, the sensitivity indicated on a small, portable meter is 1000 ohms per volt. If this meter is set on a 10-volt scale, the overall resistance of the meter is 10,000 ohms.

On circuits containing low resistances, a meter of low sensitivity may be used. In many electronic circuits, however, resistances are high and the current in them is very small. If a meter of low sensitivity is to be used, remember that the current drawn by the meter will significantly lower the voltage you are trying to measure, and the meter reading will be incorrect.

OHMMETER

The ohmmeter is widely used to measure resistance and to check circuit continuity. It is constructed with a basic meter movement and a self-contained source voltage, usually a 3-volt battery pack. Before using the ohmmeter on any circuit, the circuit must be deenergized.



289.34

Figure 9-1.—Multirange voltmeter.

The range of the ohmmeter can be increased by multiplication features. These are different sized resistors that can be placed in series with the ohmmeter's circuit, as shown in the block diagram of figure 9-2.

On some ohmmeters, you select the proper multiplication scale by operating a selector switch. On others, separate test lead jacks are used for different scales.

Before using an ohmmeter to test a circuit, the meter should be adjusted or zeroed. This will cancel out the internal resistance of the meter, and compensate for voltage variations of the self-contained battery pack. To calibrate an ohmmeter for proper operation on a selected range, first short the test leads together. Then adjust the variable resistor (rheostat), with the leads shorted, to bring the pointer of the meter to rest exactly on the zero graduation. This indicates zero resistance between the test leads. The zero reading on most series-type ohmmeters is at the right-hand end of the scale.

MEGGER

The megger is actually an ohmmeter that is capable of measuring resistance in millions of ohms (megohms). Resistances such as these will be encountered while testing conductor insulation for breakdown. The high potential needed for these tests is furnished by an internal hand-driven generator.

Meggers supplied to ships normally are rated at 500 volts, and produce from 2 to 5 amps of current. For this reason, extreme caution should be used and all safety precautions should be closely followed. Meggers are equipped with friction clutches, so that when the generator is turned at higher than its rated speed, the clutch will slip, and the output voltage will not exceed its rated value. Like the ohmmeter, the megger is to be used on circuits only after the power to the circuit has been secured and tagged.

High voltages generated by the megger are necessary to test conductors for insulation, or insulation in which breakdown under high voltage is suspected. A megger can also be used to test for grounds. A megger should never be used on an amplifier circuit, as the amplified voltages could harm the equipment. A megger reading of less than 1 megohm indicates a ground in that circuit. The 3 volts provided by the ohmmeter may not be sufficient to uncover this breakdown.

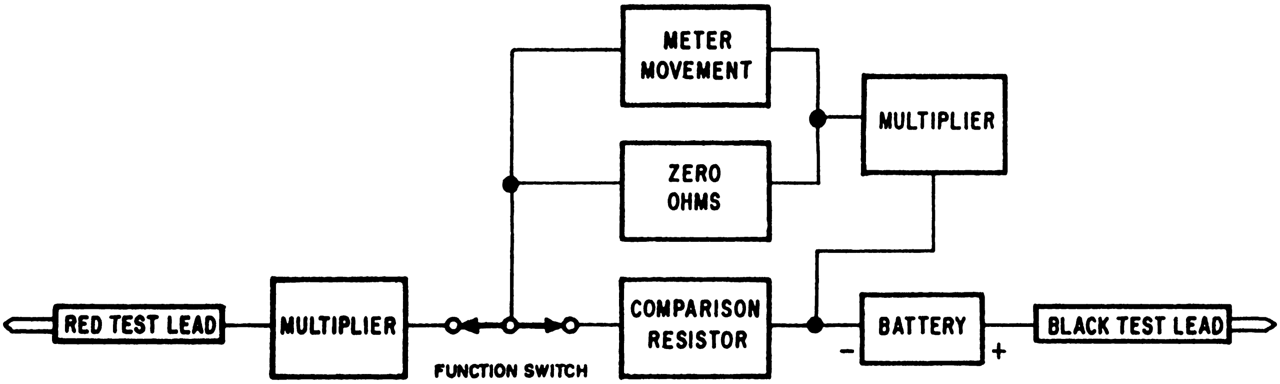


Figure 9-2.—Functional block diagram of an ohmmeter circuit.

ANSWERS TO QUESTIONS Q1 THROUGH Q6.

A1. Special- and general-purpose.

A2. Gunner's Mate (Guns) 3 & 2.

A3. Electrical, electronic, hydraulic, and mechanical.

A4. Preventive and corrective maintenance.

A5. Moisture.

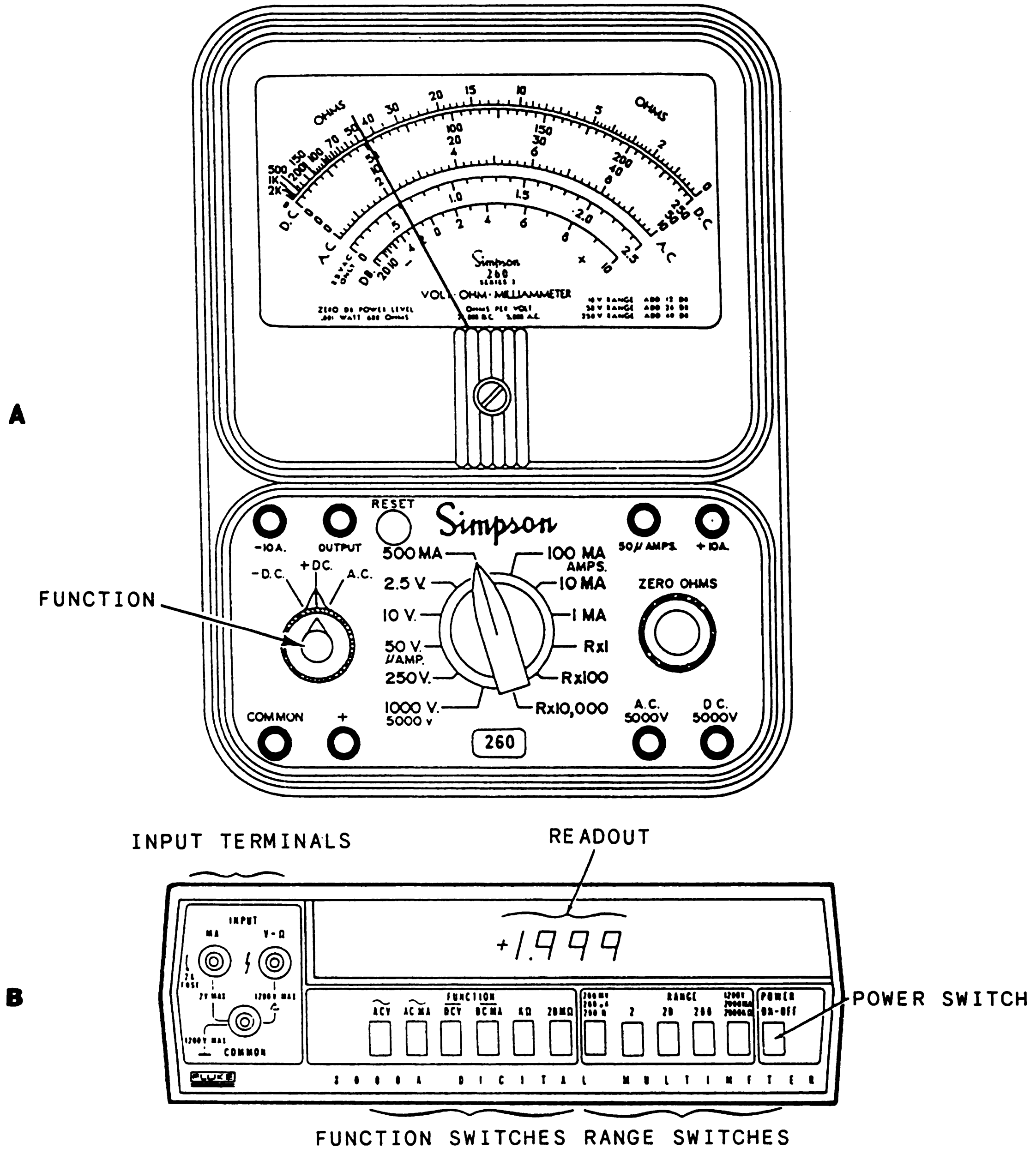
A6. That casualty is due to a faulty adjustment.

The megger can be used, with care, to test for continuity and grounds, keeping in mind that many of the elements in gunnery circuits would be damaged if subjected to 500 volts. This particular testing device is one of the mainstay tools when troubleshooting the 3"/50 cal. train and elevation motor start circuits.

MULTIMETER

The multimeter is simply a multipurpose meter that can measure resistance, current, or voltage. It is portable, and eliminates the need for carrying several meters.

The front panel is constructed and labeled in such a way as to be easily understood. Selector switches on the front panel are used to select the type of measurements to be taken, as well as the resistance, voltage, and current ranges to be tested. The multimeter also has selected pin jacks to enable you to take high voltage readings. The Simpson 260 (fig. 9-3, view A) is the most



289.23:26

Figure 9-3.—A. Simpson 260 (VOM); B. Digital voltmeter.

common multimeter you will find in our inventory. The digital voltmeter (fig. 9-3, view B) is becoming more prominent throughout the fleet, and gives more accurate readings.

TV-7D/U TUBE TESTER

The TV-7D/U tube tester, is designed to test and measure the mutual conductance of receiving electron tubes and many of the smaller transmitting tubes. Rectifier and diode tubes can be checked for emission. Two other tube tests conducted with this meter are the short test (for shorts between tube elements) and the gas test. Once all our 3″/50 cal. tube-type amplifiers are replaced with the new Mk 117 solid state amplifiers, this particular piece of equipment will no longer be a part of our test equipment inventory.

Q7. With the selector switch of a voltmeter on 100 volts, and the meter sensitivity at 1000 ohms-per-volt, what is the overall resistance of the meter?

Q8. On an ohmmeter, what two means of selecting the proper multiplication scale are available to you?

Q9. Like the ohmmeter, the megger is to be used only after what action has taken place?

Q10. What is the most common multimeter you will find in your test equipment inventory?

Q11. A megger reading of less than 1 megohm is indicative of what casualty?

SHIPBOARD TESTS AND TEST EQUIPMENT

Weapons system shipboard performance tests determine whether the elements of a ship's weapons system function within design specifications under all operating conditions. Most performance tests are conducted annually. Note, however, that existing conditions, such as a suspected malfunction, may require that certain tests be performed more frequently.

Typical reasons for conducting such operational performance tests are new installations, regular yard overhaul, replacement of major components, or repair of a major casualty. In case of major casualties, only the affected portion of the system need be activated and tested.

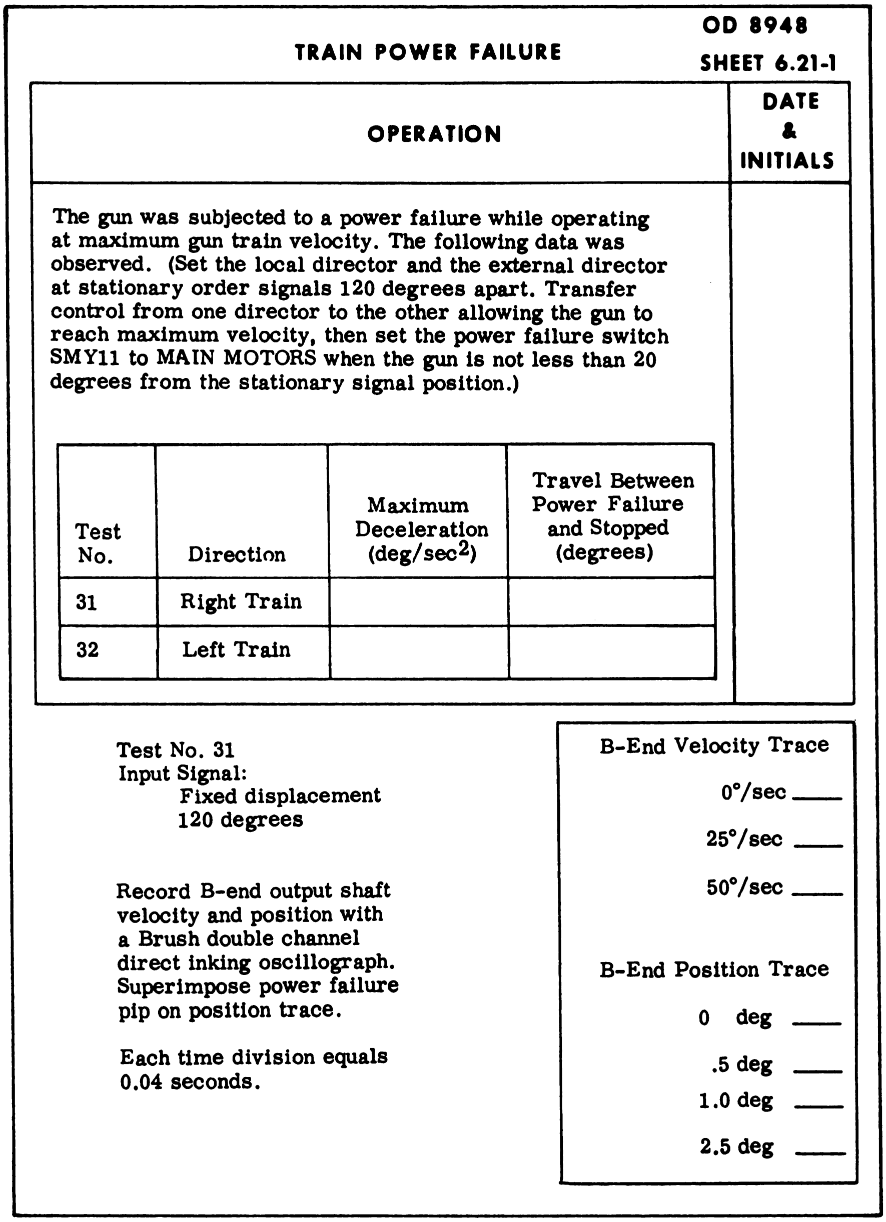
Operational performance tests are also required to determine whether a gun mount or launcher's train and elevation power drives follow order signals accurately, or to check specific equipment such as fuze setters and ammunition handling equipment.

Regardless of the purpose of the test or the frequency with which the tests are conducted, the personnel conducting the tests must be familiar with both the testing procedure and the equipment used. Each unit of a ship's major weapons system (gun mount, launcher, director, and other ordnance equipment) has separate weapons system ODs that list all the individual shipboard tests conducted at the time of initial installation.

COMPARING PERFORMANCE DATA

Following shipboard installation, units of a ship's weapons system are subjected to a complete performance test as detailed in a shipboard installation test instruction OD for each unit installed. The results of these tests are logged in the ship's copy of the OD for future reference. The resultant test tracings of the installation performance tests are reproduced as an appendix to each OD. Later, after conducting performance tests of a gun mount or launcher, the test results are compared with those obtained at installation. The information obtained from these tests could result in detection of a significant performance deterioration that could warn of impending failure, and may indicate the need for corrective maintenance, repair, or overhaul.

The tests listed in the installation ODs generally are arranged so that each group of tests is described on a test lead sheet, which is followed by one or more test worksheets. The worksheets provide scales to facilitate the reading of oscillograph traces for various tests (fig. 9-4). After completion of these tests, the oscillograph traces should be attached to the respective worksheets. A list of shipboard installation tests instructions ODs can be found in OP 0. When performing any tests employing a graph-type paper such as that used with an error recorder, consideration should be given to the characteristics of the trace being



OD 8948

TRAIN POWER FAILURE

SHEET 6.21-1

OPERATION	DATE & INITIALS
The gun was subjected to a power failure while operating at maximum gun train velocity. The following data was observed. (Set the local director and the external director at stationary order signals 120 degrees apart. Transfer control from one director to the other allowing the gun to reach maximum velocity, then set the power failure switch SMY11 to MAIN MOTORS when the gun is not less than 20 degrees from the stationary signal position.)	

Test No.	Direction	Maximum Deceleration (deg/sec^2)	Travel Between Power Failure and Stopped (degrees)
31	Right Train		
32	Left Train		

Test No. 31
Input Signal:
Fixed displacement
120 degrees

Record B-end output shaft velocity and position with a Brush double channel direct inking oscillograph. Superimpose power failure pip on position trace.

Each time division equals 0.04 seconds.

B-End Velocity Trace

0°/sec ____

25°/sec ____

50°/sec ____

B-End Position Trace

0 deg ____

.5 deg ____

1.0 deg ____

2.5 deg ____

Figure 9-4.—Test worksheet.

conducted. No attempt should be made to duplicate any previous traces because there are too many variables involved. You should make every attempt to obtain results that are within the tolerances recorded on the worksheet for the test being conducted.

TESTING PROBLEMS

Information taken from some current surface ships inspection and survey (INSURV) reports revealed that one of the major deficiencies found within a weapons system was that many of the system's component power drives were sluggish, and that system performance dynamic tests were not conducted or out of date. It was also found that some ships having test equipment such as dummy directors and error recorders were not using them because the personnel were unable to use them. As a GMG 1, it will be your responsibility to ensure that such tests are conducted properly by your crew or an assisting activity.

The following information will explain some types of test equipment used to conduct operational performance tests. Also, supply information on the types of test traces, the reading of test traces, the precautions to be observed, and the methods used to calibrate the recording oscillographs will be discussed.

TYPES OF TRAIN AND ELEVATION TRACES

Normally, three types of error traces are taken with test instruments. The three types are the B-end error traces, the B-end position traces, and the B-end velocity traces.

B-End Error Trace

B-end error trace voltages are obtained from the 36X CT geared to the B-end response shafts in the respective receiver regulators. The synchro rotors are geared to the 36X response in the regulator, while the stators are connected electrically to the stators of the 36X synchro transmitters in the local or external test director. The rotor output voltages, which are 400-hertz ac, represent the error between the local or external director and the B-end response shaft. The output voltages are circuited through a dummy director and then recorded on an error recorder.

B-End Position Trace

B-end position traces are obtained from the same 36X CT that furnishes the B-end error trace voltages. Through proper switching of the test equipment, the output voltages produced will indicate B-end position and not B-end error. The position output voltages are also circuited through a dummy director and recorded on a error recorder.

B-End Velocity Trace

B-end velocity trace voltages are obtained from the dc tachometer generators located in the respective receiver-regulators. These tachometer generators are geared directly to the B-end response gearing and furnish a dc voltage that is proportional to the B-end velocity. The tachometer output is circuited through test instrumentation and then recorded by the error recorder.

Q12. The list of shipboard installation instructions can be found in what two publications?

Q13. What component in the receiver-regulator provides you with the B-end velocity trace voltage?

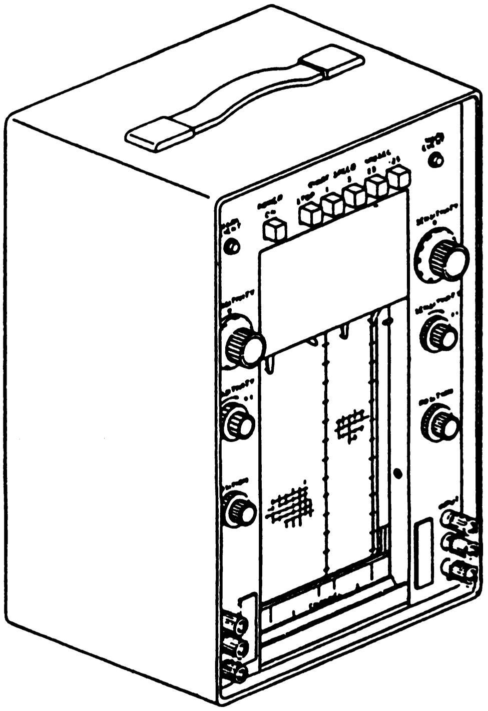


Figure 9-5.—Error recorder (oscillograph) Mk 20 Mod 0.

ANSWERS TO QUESTIONS Q7 THROUGH Q11.

A7. 100,000 ohms.

A8. Either a selector switch or separate test lead jacks.

A9. Only after circuit power has been removed.

A10. The Simpson 260.

A11. A ground in the circuit.

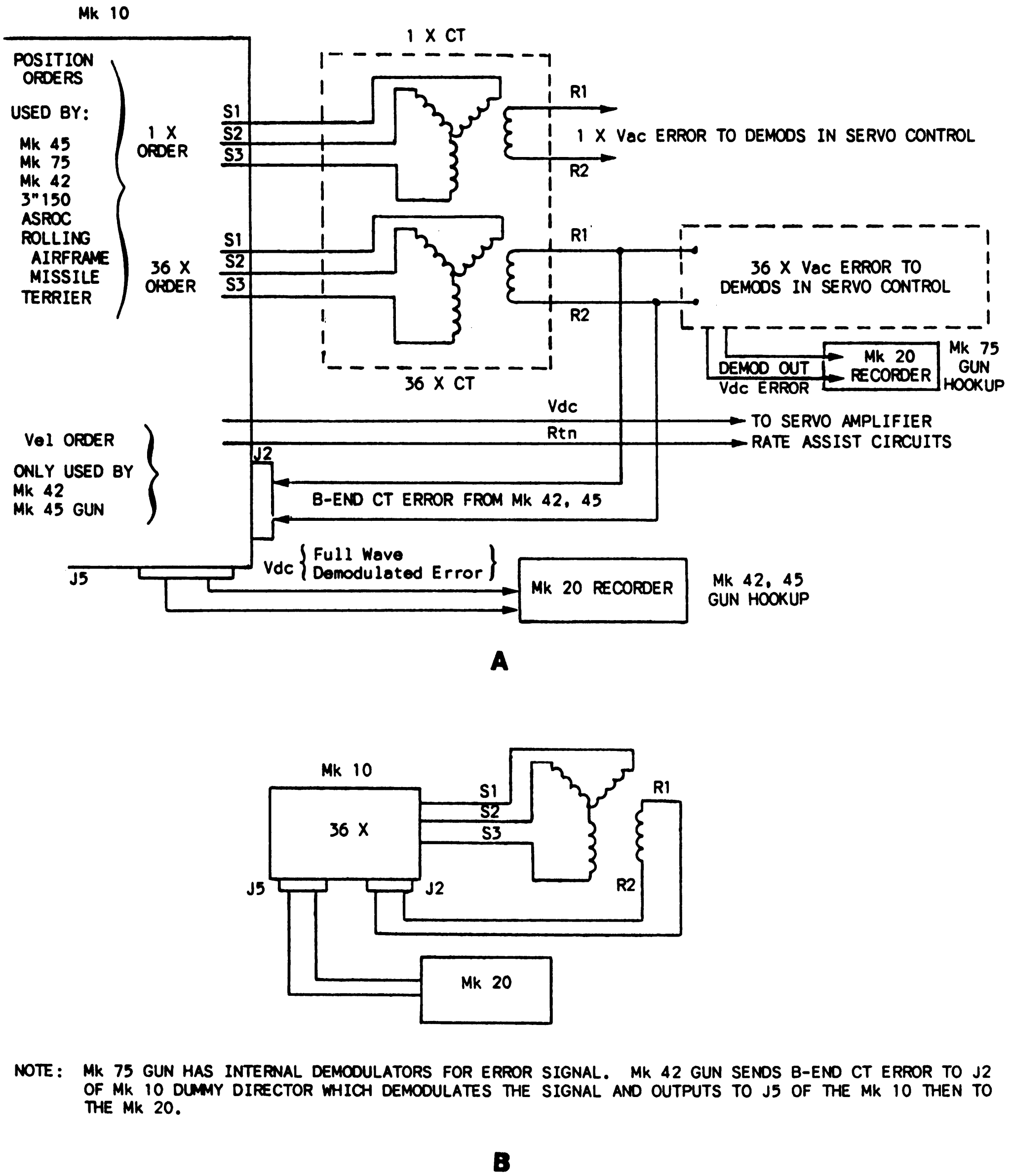
TEST INSTRUMENTATION

Two of the gun test equipments used during performance testing are the error recorder (oscillograph) and the external (dummy) director. These items are no longer listed as part of ship's special tools and are procured only through mobile technical units, NAVSEA field service offices, or ship repair facilities.

Error Recorder (Oscillograph)

The error recorder Mk 20 Mod 0 (see fig. 9-5) is to be used with the external (dummy) director Mk 10 Mod 0. It records the functional data from the dummy director to record functional traces in train, elevation, or fuze setting traces.

Since the oscillograph has two channels, two different traces may be taken at the same time. This allows corresponding trace results to be compared to learn more about the gun mounts' operation. Normally, three types of these traces are taken with test instrumentation—B-end error, position, and velocity traces. Figure 9-6, view A, shows the basic hook up of the Mk 10 dummy



NOTE: Mk 75 GUN HAS INTERNAL DEMODULATORS FOR ERROR SIGNAL. Mk 42 GUN SENDS B-END CT ERROR TO J2 OF Mk 10 DUMMY DIRECTOR WHICH DEMODULATES THE SIGNAL AND OUTPUTS TO J5 OF THE Mk 10 THEN TO THE Mk 20.

53.371

Figure 9-6.—A. Standard hook-up for Mk 10 and Mk 20; B. Standard hook up for Mk 10 internal test.

director in conjuction with the standard gun system with output to the Mk 20 error recorder. Figure 9-6, view B, shows the internal test hook up for verifying the Mk 10 dummy director. Figure 9-7 shows a sample SHM trace with the velocity set at 2V/mm and the error trace at 200MV/mm at 25mm/sec. Figure 9-8 shows a full cycle trace of an error and velocity output trace in the SHM mode.

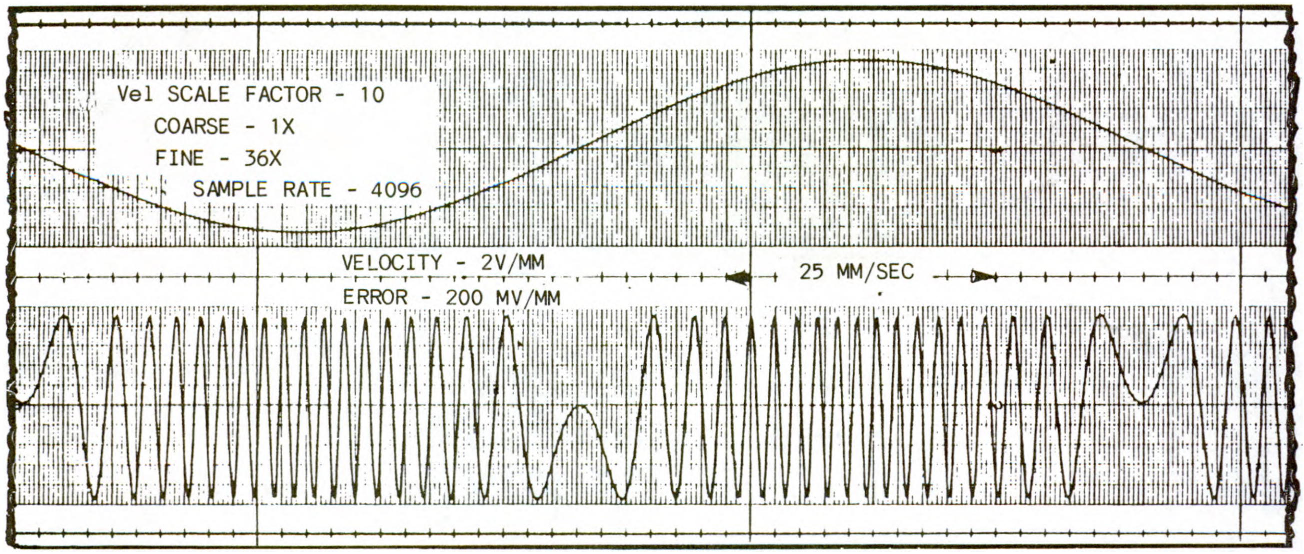
> **NOTE**: Always calibrate the oscillograph before recording any traces. Calibration procedures are provided with the operator's manual of the oscillograph.

External (Dummy) Director

This instrument can supply three types of signals—a constant velocity signal, a simple harmonic motion signal, and a stationary signal for testing train and elevation power drives and fuze setters. The Mk 10 Mod 0 external (dummy) director (fig. 9-9) contains synchro transmitters that generate electrical signals used to perform dynamic and performance accuracy tests of the train and elevation, and some fuze setting systems.

CONSTANT VELOCITY (CV) SIGNAL.— If a constant velocity (CV) order is selected at the director, the ordnance unit under test will travel the direction ordered until the dummy director is stopped or altered. If the order is not altered or stopped, the unit will travel until it engages a limit stop which will bring the unit to a halt. The dummy director can order a variety of speeds for right train, left train, and elevation or depression of a gun barrel or launcher guide. The unit's rate of movement is constant during CV travel once the unit attains the directed speed after starting.

SIMPLE HARMONIC MOTION (SHM).— A simple harmonic motion (SHM) order signal (also called roll) can be produced by the dummy director at a variety of amplitudes and periods. When the director commences transmission of the SHM order, the units will move from starting point to the angle selected, then stop, reverse, and return to the starting point. The unit will continue to roll to an equal angle on each side of the fixed



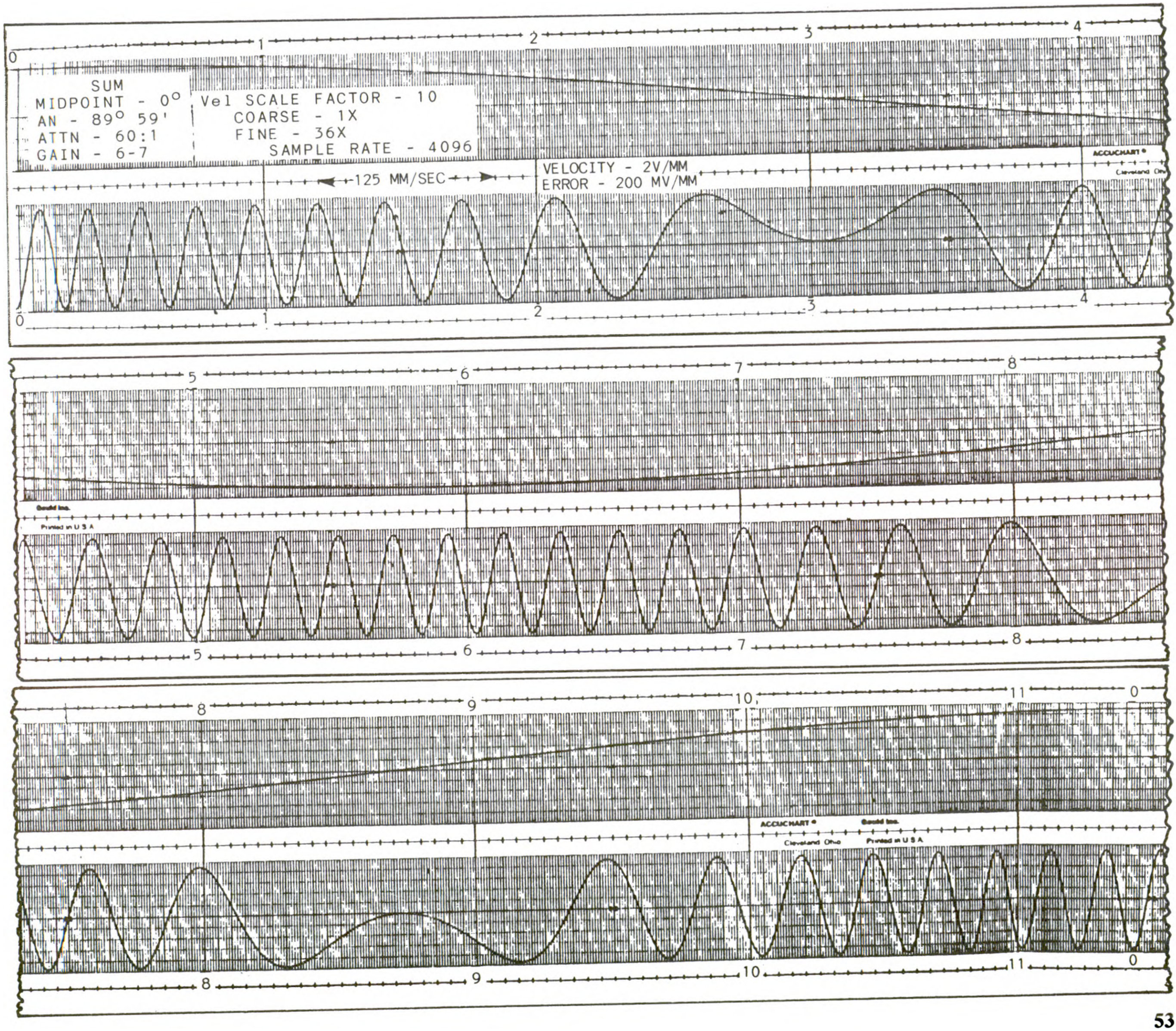
53.372

Figure 9-7.—Error and velocity output trace in SHM mode at 25mm/sec.

ANSWERS TO QUESTIONS Q12 AND Q13.

A12. OP 0 and OD 39397, Index of Technical Manuals for Conventional Ordnance.

A13. The dc tachometer generator.



53.373

Figure 9-8.—Error and velocity output trace in SHM Mode at 125mm/sec.

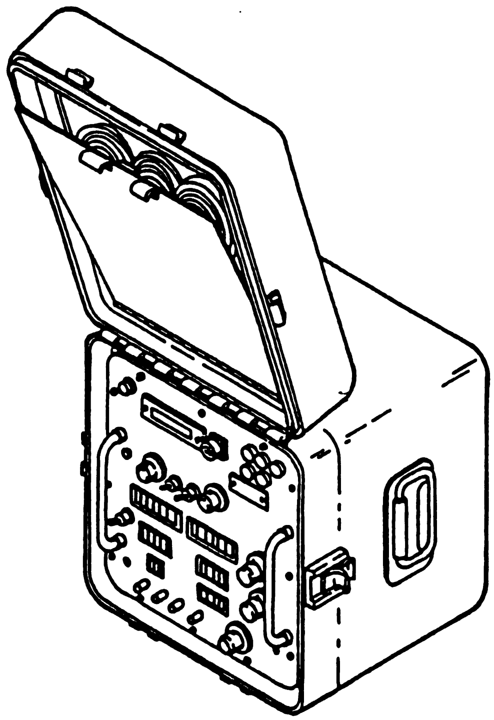


Figure 9-9.—Dummy director Mk 10 Mod 0.

center point until the director orders are altered or discontinued.

STATIONARY SIGNAL.—When a manually set stationary signal is used, a position should be selected so that the units will engage the limit stops. The stationary order signal from the dummy director will drive the unit until it arrives at the ordered position. The unit remains at this position without further movement until the director's setting is changed.

GUN BATTERY TEST EQUIPMENT

In most cases, performance and dynamic accuracy tests are conducted by tender or shore activities. The reason for this is that most ships do not carry the test instruments on board as part of a ship's test equipment allowance. The type of tests conducted and the equipment used are determined by the classification of the mount and by the activity conducting the test.

AMPLIFIER ALIGNMENT

Before any performance testing can be conducted on ordnance equipment, each amplifier within the system must be balanced. In the 5"/54 Mk 42 Mods 9 and 10 gun mounts, both train and elevation amplifiers have adjustments which control the gain settings for gun velocity, stroke balance, and director velocity. These settings are recorded in the shipboard installation test OD and should be checked before any amplifier alignment is conducted.

There are three balance adjustments that can be made on most gun system amplifiers. The purpose of these adjustments is to ensure that when replacement parts are incorporated into a servo system, such as amplifier module boards, the servo system is adjusted and aligned to the new parts. To check a system for proper amplifier alignment, tests are performed at each amplifier using the amplifier's control panel, train and elevation receiver-regulator, and system test equipment. The three tests conducted are the stroke balance, the director velocity, and the velocity potentiometer.

The purpose of the stroke balance adjustment is to ensure that when the gun is at 0 degrees train and 4700 minutes of elevation, the stroke balance potentiometer stops the hydraulic B-end motion, and that both the direction and magnitude of the B-end is zero.

The stroke response adjustment is made at the receiver-regulators to stop the B-end motion. This is accomplished by adjusting the wiper arm of the stroke response potentiometer (SRP) with no signal from the amplifier. This should be done before adjusting for director velocity.

To adjust for director velocity, set up the dummy director for 0 degree train and 4700 minute elevation order. Place the gun mount in dummy director control and position the velocity adjustment potentiometer on the amplifier to zero. Set the dummy director for CV increasing and decreasing order signals. You are now ready to conduct an error and velocity trace.

At the amplifier, adjust the DIR-VEL controls until the error trace is the same magnitude and direction from zero for both increasing and decreasing order signals. If the minimum error obtained for an increasing order deflects the pen one line to the right of zero, a decreasing order should also deflect the pen one line to the right of zero.

The velocity potentiometer is adjusted at the amplifier until the B-end error is a minimum of zero with the dummy director set for a 30-degree, 9-second SHM signal. This completes the procedures for amplifier alignment. Shipboard performance tests can now be conducted.

Q14. What are the three types of error traces recorded on the oscillograph?

Q15. What three types of signals are provided by the external (dummy) director?

Q16. The wiper arm of the stroke response potentiometer is adjusted to stop what action?

READING TEST TRACES

Test traces are read like ordinary graph curves. They illustrate the error, position, or velocity of a power drive at the time the tests were made. Traces below the zero reference line are the opposite phase from traces above the zero reference line. Be certain to check the following when reading test traces: (1) type of test being checked, (2) type of trace being used, (3) test conditions, (4) calibration of the graph, and (5) time allotted for each of the vertical graph divisions.

Keep in mind that the error and position trace voltages are generated by the 36X synchros and difficulty may arise in reading test traces if the error or position readings are greater than 2.5 degrees. A gun mount movement of 2.5 degrees corresponds to a 36X synchro movement of 90-degrees. (A 36X synchro is geared to move 36 degrees for every 1 degree of gun movement.) Since a synchro generates maximum output with a 90-degree rotor or stator displacement, the maximum trace indication occurs at an error or position displacement of 2.5 degrees. This necessitates the use of a special method to indicate error or position traces greater than 2.5 degrees.

Since a complete revolution of a 36X synchro corresponds to 10 degrees of gun movement, one complete cycle of the position or error trace corresponds to 10 degrees of gun movement. For example, if the error or position trace consists of 6-1/2 cycles, the trace will measure 65 degrees of position trace. The 65 degrees is calculated by multiplying 10 (the degrees of gun movement per revolution of the 36X synchro) times 6.5 (the number of error or position synchro revolutions).

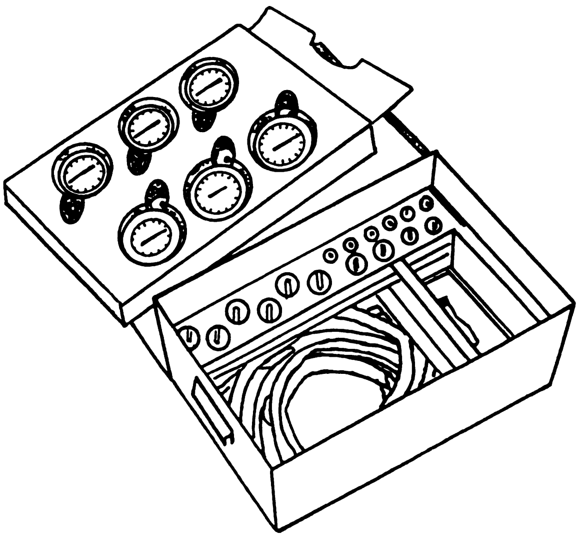
For B-end position traces of less than 5 degrees, you should use the calibration curve to determine the exact B-end position. An example of the calibration curve has been provided in figure 9-7.

> **NOTE:** One feature of the error recorder used in ordnance testing is that the chart paper is common to all test equipment.

HYDRAULIC TEST KIT

A hydraulic test kit (fig. 9-10) consist of a portable metal box that contains pressure gages with scales ranging from 0/100 to 0/3000 pounds per square inch (psi), a set of regulating valves, a test hose, and an assortment of special adapters, pipe nipples, and couplings. This test kit is a pressure testing device used for checking the hydraulic fluid pressures at any point within a weapon system.

An example of the kit's use would be to check the servo and supercharge pressures of a hydraulic system. In the 5"/54 gun mounts, the servo pump produces 200 psi and the supercharge pump produces 400 psi pressure; which in turn, provides a regulated 100 psi to the transmission. These



53.306

Figure 9-10.—Hydraulic test kit.

pressures can be checked by removing the test plugs (location shown in figure 9-11) and using the proper adapters and test gages at these points to measure hydraulic pressures. The pressure tolerances vary with each hydraulic system but usually allow a difference of plus or minus 10 to 20 psi.

DUMMY FUZE TEST GAGE

The operation of the fuze setting devices for the 5"/54 gun mounts are checked by means of a dummy director and dummy fuze test gage (fig. 9-12, views A and B). The dummy director transmits synchro signals to the fuze setter, the fuze test gage permits comparison of position-time settings between the dummy director and fuze setter.

The dummy fuze test gage consists of a dummy fuze, a dial, and a vernier index. The dial is calibrated in seconds to agree with the fuze settings. The vernier index permits readings of fuze settings to 0.01 second.

SAFETY

A lot of material has been written on this subject. Safety precautions are listed in many publications, such as United States Navy Ordnance Safety Precautions, OP 3347, and the various equipment OPs. It is up to you to familiarize yourself with these regulations. Safety precautions found in OPs and posted on the mounts must be followed strictly, of course; but in general, they apply to the operating procedures of the equipment. In unforseen circumstances, you must use your own ability and initiative to prevent accidents. For this reason, it would be well for you to review a few basic causes of accidents.

Inexperience can be the cause of accidents regardless of how careful we tend to be. The best solution to this problem is to ask questions about equipment with which you are not familiar. Work into a job gradually, and be certain of the correct procedures. **Never guess!**

Overconfidence can come to young and old alike, usually associated with experience. We all

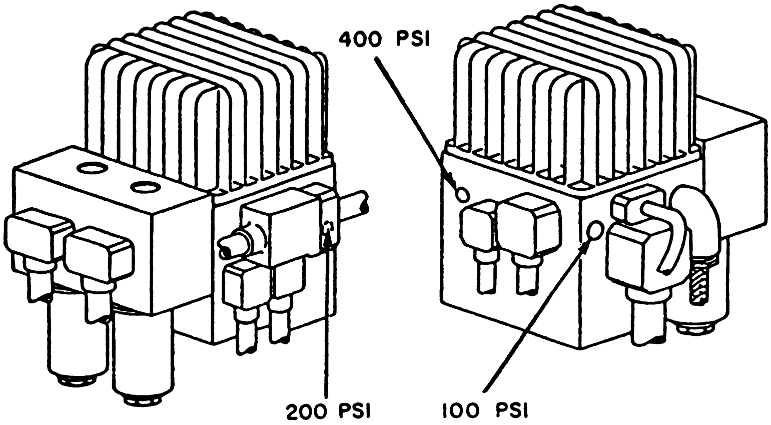


Figure 9-11.—Hydraulic test points.

ANSWERS TO QUESTIONS Q14 THROUGH Q16.

A14. B-end error, velocity, and position traces.

A15. A constant velocity signal, a simple harmonic motion (SHM) signal, and a stationary signal.

A16. Unwanted B-end motion when no signal is applied to the amplifier.

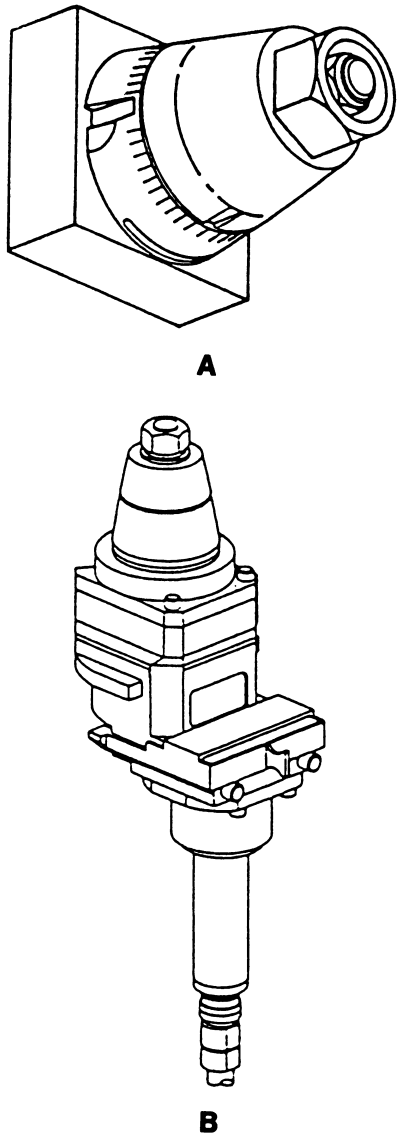


Figure 9-12.—Dummy fuze test gages: A. Mk 42; B. Mk 45.

tend to grow overconfident when we become familiar with a particular job. Briefly, you must be confident that you know the job, but be aware that overconfidence invites mistakes.

Carelessness is a human failing which we must all try to overcome. It is restricted to neither the eager beginners nor the experienced technicians. Carelessness can best be corrected by including safety in good working habits and housekeeping. Some helpful safety pointers are listed here for your review.

1. Gather as much information as possible on unfamiliar equipment before working on it.

2. Do not place tools where they can be accidently dislodged into your work.

3. Use insulated tools, if they are available; otherwise, wrap friction tape around those you have.

4. If power has been secured while working on a circuit, tag the circuit at the place where it was deenergized (fuze box, circuit breaker, etc.). Information on this tag should include the name of the person who had the circuit secured, and for what reason. Refer to OPNAVINST 3120.32 (tag-out procedures).

5. Do not take another person's word that a circuit has been secured. Test it yourself. This is especially important when continuing a job somebody else has started.

6. Attempt to keep one hand free at all times when working with high voltage, especially if you are working on the inside of the unit. This will prevent current from flowing across your body if you should accidently come into contact with a hot wire. Place an insulated rubber mat on the deck to stand on whenever working on electrically energized equipment.

7. Gather all tools and reference data necessary to complete a job before starting it. Sending a striker for an OP during the actual work not only wastes time, but prevents the trainee from learning.

8. Handle your meters with care. Using them as stepladders or miniature workbenches is likely to result in some damage.

9. Never bypass safety interlock linkages or switches. If you do, casualties to both equipment and personnel may result.

10. Establish good communications between you and the mount and its remote control station, and/or the director, when the mount is going to be controlled by that station. This is to alert personnel at the mount to any possible danger.

11. If at all possible, always ensure that no live ordnance is present before working on equipment.

Q17. What is the range of the pressure gages (in PSI) contained in the hydraulic test kit?

Q18. What is the best solution to any problem dealing with inexperience?

SUMMARY

In this chapter you have been given some direction as to where you can go to receive additional instruction on certain pieces of test equipment. It is most likely that you may never have to use a dummy director or an oscillograph, but in the event you do, it is to your advantage to have as much knowledge about these equipments as you can muster. We have discussed meters, meggers, special- and general-purpose test equipment, and maintenance.

As is the case in any safety situation, there is no better learning tool than experience. It is imperative that you train yourself and those who look to you for guidance on safety. Safety precautions cannot be overemphasized, nor should they ever be taken lightly. Each system OP devotes a chapter to safety; and as a rule, these safety procedures are usually written in blood—meaning that someone in the past has made a costly mistake.

REFERENCES

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

Mk 45 Mod 1, Description, Operation and Maintenance, Vol. 1 SW323-D1-MMO-020/GM Mk 45 Mod 1, Naval Ship Weapon Systems Engineering Station (NSWSES 5700), Port Hueneme, Calif., 1986.

Navy Electricity and Electronics Training Series, Module 16, *Introduction to Test Equipment*, NAVEDTRA 172-16-00-84, Naval Education and Training Program Development Center, Pensacola, Fla., 1984.

Dummy Director Mark 10 Mod 0, NAVSEA OP 4506, Naval Ship Weapon Systems Engineering Station (NSWSES 5700), Port Hueneme, Calif., 1979.

ANSWERS TO QUESTIONS Q17 AND Q18.

A17. 0/100 to 0/3000 psi.

A18. Ask questions—never guess!

CHAPTER 10

FUZE-SETTING DEVICES

Although the VT (proximity) fuze has largely replaced the mechanical time fuze for primary use against antiaircraft (AA) targets, the latter is still far from obsolete. Mechanical time fuzes (MTFs) are still used for AA barrage purposes, for illumination, and as a backup for the variable time (VT) fuzed projectiles.

This chapter is written to broaden your understanding of the devices that are currently being used in the fleet to rapidly, accurately, and automatically set mechanical time fuzes. Fuze-setting equipment installed in the 5″/38 twin mount and in the 5″/54 Mk 42 and Mk 45 gun mounts will be described here in some detail as typical examples.

FUZE-SETTING EQUIPMENT FOR THE 5″/38 TWIN MOUNT

The fuze-setting mechanism for the 5″/38 twin mount consists of (1) a fuze-setting indicator-regulator, (2) projectile flights, and (3) fuze-setting chains. These three components, shown schematically in figure 10-1, will be referred to as a regulator, flights (pots), and fuze chains in the following discussion.

INDICATOR-REGULATOR

The regulator sets the fuze by controlling the position of the fuze chains. The fuze chains are endless chains mounted on the outboard sides of the hoist chain (fig. 10-1) and are driven by the regulator. The flights (sometimes called fuze pots) are secured to the hoist chain, spaced equally one from the other. The hoist chain reverses direction with each cycle; therefore, when one flight goes up, the other comes down. The flights not only support and hoist the projectile, but set the fuze as well. How this is accomplished will be explained in the following paragraphs as we study the main components of the 5″/38 fuze-setting equipment in a little more detail.

FLIGHTS

Each flight (fig. 10-2, view A) consists essentially of an outer socket that is attached to the hoist chain, and an inner socket mounted on ball bearings so that it can rotate within the outer socket. The inner socket is geared to a sprocket, which engages the fuze chain. Thus, any movement of the fuze chain will cause the inner socket to rotate. Also, movement of the flight itself, as it is being hoisted or lowered by the hoist chain, will cause the inner socket to rotate as the sprocket walks up the fuze chain.

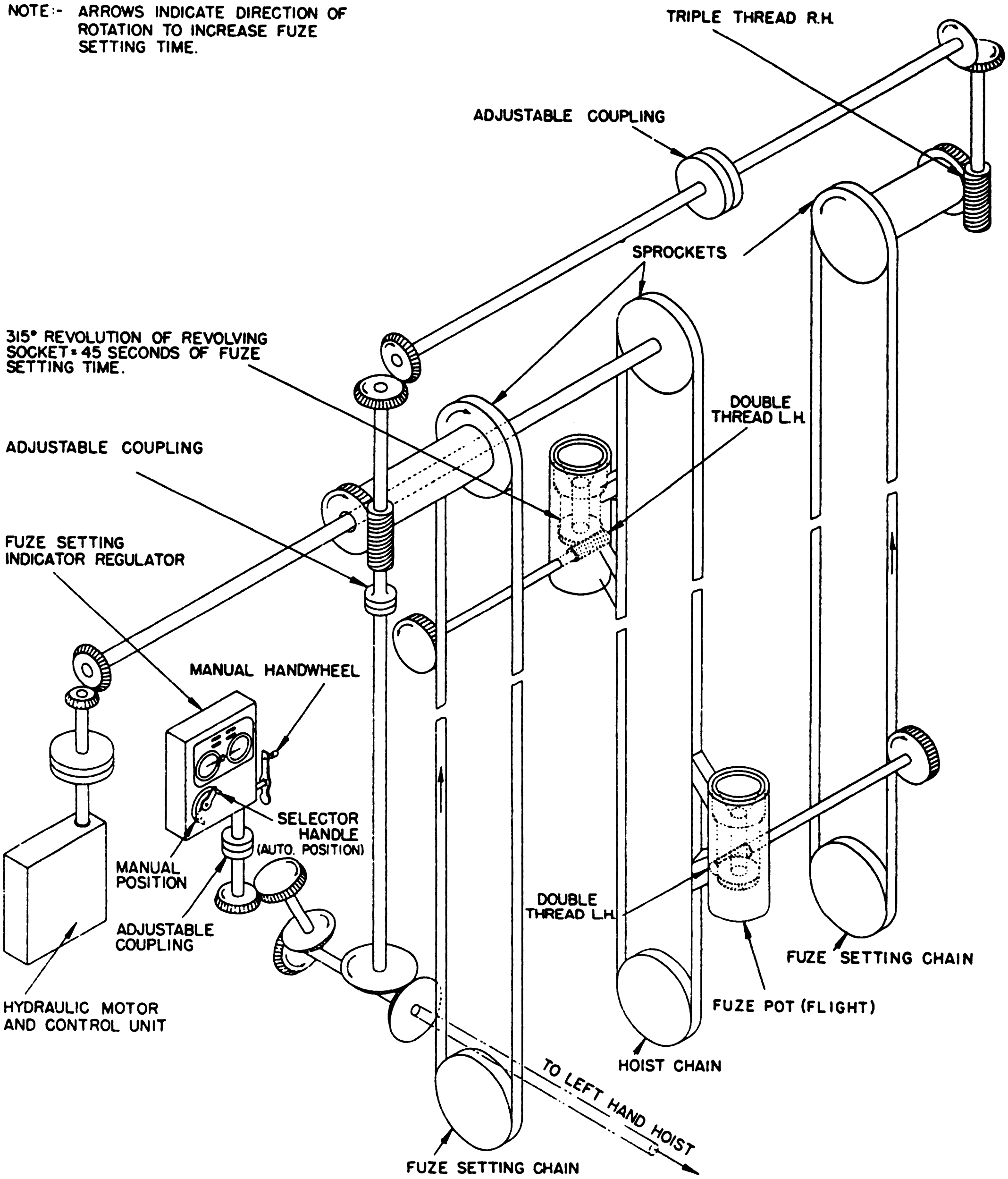
Set into the upper part of the inner socket are two spring-loaded pawls (fig. 10-2, view A). In top of the outer socket is a V-shaped slot. The V-shaped slot does not rotate, but the spring-loaded pawls (being part of the inner socket) rotate with the inner socket when either the flight is moved by the hoist chain, or the fuze chain is moved by the regulator.

Q1. *What are the three components that make up the fuze-setting mechanism of the 5″/38 mount?*

Q2. *How does the regulator set the fuze?*

FUZE CHAINS

Looking again at figure 10-1, the fuze chains are schematically drawn to appear wide apart to make it easier to read the schematic. Actually, the two fuze chains and the hoist chain are very close together, as shown in figure 10-2, view A. The hoist chain is driven by the hoist hydraulic power drive. The fuze chains are driven by the regulator. The regulator can be actuated either by transmitted


NOTE:- ARROWS INDICATE DIRECTION OF ROTATION TO INCREASE FUZE SETTING TIME.
TRIPLE THREAD R.H.
ADJUSTABLE COUPLING
SPROCKETS
315° REVOLUTION OF REVOLVING SOCKET = 45 SECONDS OF FUZE SETTING TIME.
DOUBLE THREAD L.H.
ADJUSTABLE COUPLING
FUZE SETTING INDICATOR REGULATOR
MANUAL HANDWHEEL
SELECTOR HANDLE (AUTO. POSITION)
MANUAL POSITION
ADJUSTABLE COUPLING
DOUBLE THREAD L.H.
FUZE SETTING CHAIN
FUZE POT (FLIGHT)
HYDRAULIC MOTOR AND CONTROL UNIT
HOIST CHAIN
TO LEFT HAND HOIST
FUZE SETTING CHAIN

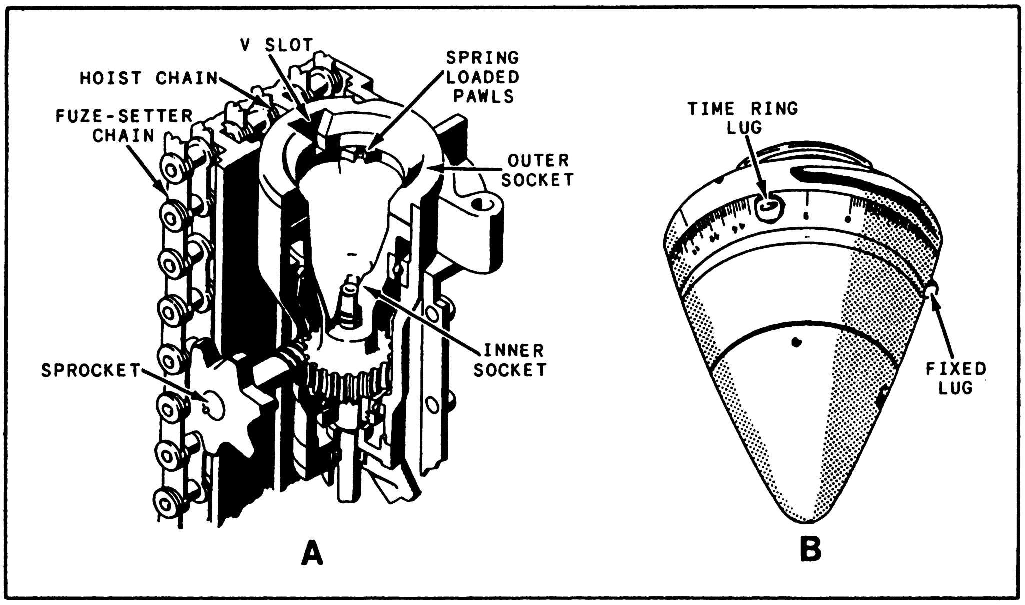
53.234

Figure 10-1.—5"/38 projectile hoist. Hoisting and fuze-setting gear (schematic).

ANSWERS TO QUESTIONS Q1 AND Q2.

A1. The indicator-regulator, fuze chains, and flights.

A2. By controlling the position of the fuze chains.



84.15

Figure 10-2.—Fuze-setting mechanism, 5"/38 caliber gun. (A) Projectile flight; (B) Fuze.

data from the fire control system (in automatic) or by a hand crank (in local).

As can be seen in figure 10-1, each fuze chain is geared to and serves a single flight. (It should be pointed out here that figure 10-1 portrays but one of the two hoists actually used in the twin 5"/38 mount. The fuze chain arrangement is identical for each of the two hoists and is driven in unison by the same regulator. Each of the hoist chains, however, is driven by its own individual hydraulic power drive unit.)

SETTING THE FUZE

A fuze is set by rotating the time ring lug (fig. 10-2, view B). In operation, the projectile is put into the flight at the bottom of the hoist so that the fixed lug on the fuze goes into the V-shaped slot. The pawls in the inner socket are then in the same plane as the fuze's time ring. When the flight begins to go up with the hoist chain, the fuze chains, which are moved only by the regulator, do not move with it. The sprocket engaging the fuze chain, therefore, rotates as it walks up the chain, turning the inner socket. At some point in the flight's upward travel, depending on the setting at the regulator, the spring-loaded pawls in the inner socket will have turned far enough to engage the lug on the fuze time ring. As the flight continues on up the hoist, the fuze time ring will be turned along with the spring-loaded pawls. The mechanism is adjusted so that, upon arrival at the top, the fuze is set in accordance with the fuze-setting order at the regulator. Should the projectile not be removed immediately, all changes in fuze-setting order will continue to be set into the fuze as the regulator moves the fuze chains accordingly.

Now that we have seen the results of the regulator's output, let us take a look at the regulator itself.

Q3. What component drives the hoist chain?

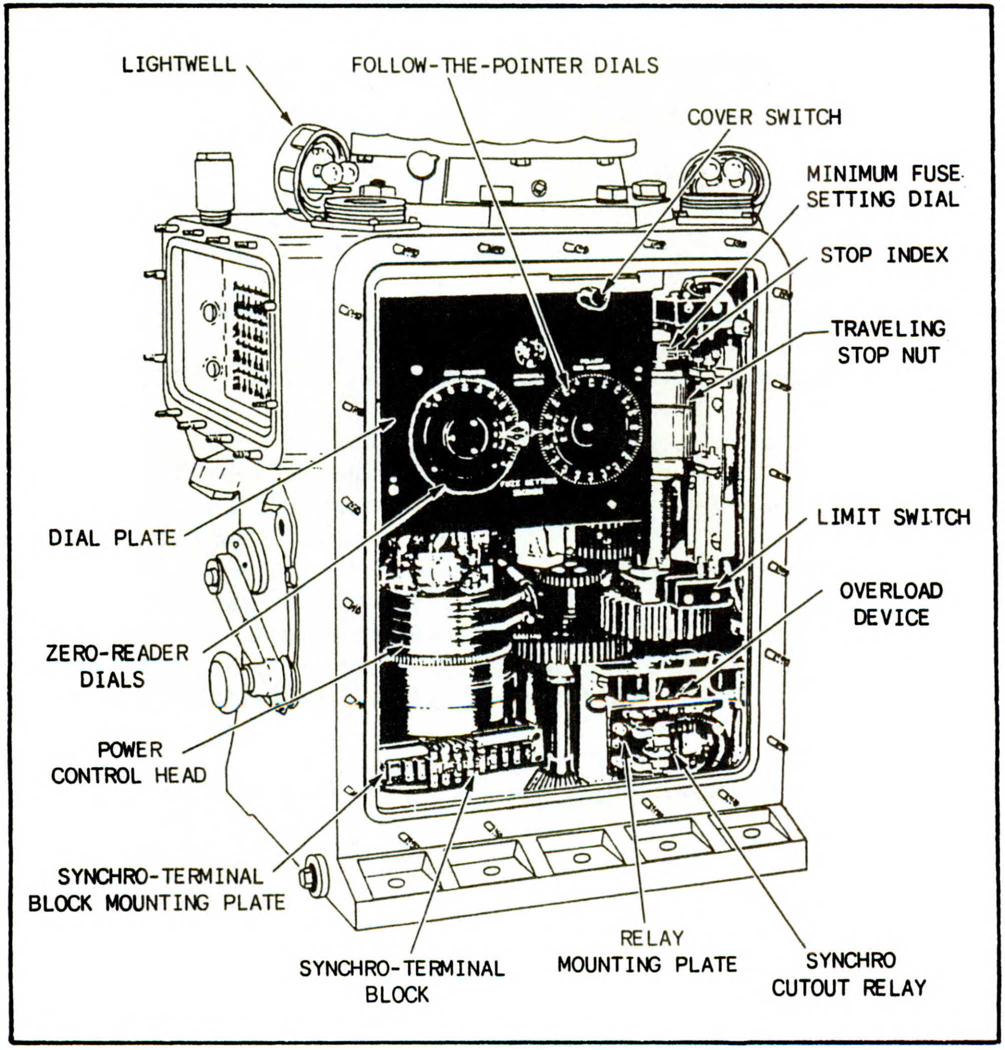
Q4. Fuze setting is accomplished by what action in the 5"/38 mount?

MK 9 FUZE-SETTING INDICATOR-REGULATOR

The Mk 9 Mod 0 regulator is an assembly of dials, electric motors, and gearing (fig. 10-3) that receives electrical fuze-setting orders from the computer and transmits those orders mechanically to the fuze-setting mechanism of the projectile hoist. The regulator can be set for either manual or automatic control by means of a selector lever.

In manual control, the gun crew fuze-setter operator turns the manual handwheel to actuate the chain-setting drive, and the setting is effected by one of the following methods:

1. By matching pointers: The fuze-setter operator matches pointers on two sets of regulator dials, one set of which is actuated by electrical signals from the computer, the other set by rotation of the manual handwheel.



53.235

Figure 10-3.—Mk 9 Mod 0 fuze-setting indicator-regulator. Right front view (covers removed).

ANSWERS TO QUESTIONS Q3 AND Q4.

A3. The hoist hydraulic power drive.

A4. By rotation of the time lug.

2. By setting the desired fuze time on the regulator dials: The manual handwheel is turned until the dials indicate the desired fuze time opposite fixed index marks. This method is used when indicating signals are not available from the computer.

In automatic control the manual handwheel is disengaged, and the fuze chains are automatically positioned by an electric power drive in the regulator. This power drive is controlled by electrical signals from the computer.

To learn more about its inner workings, we will review the more important components of the regulator.

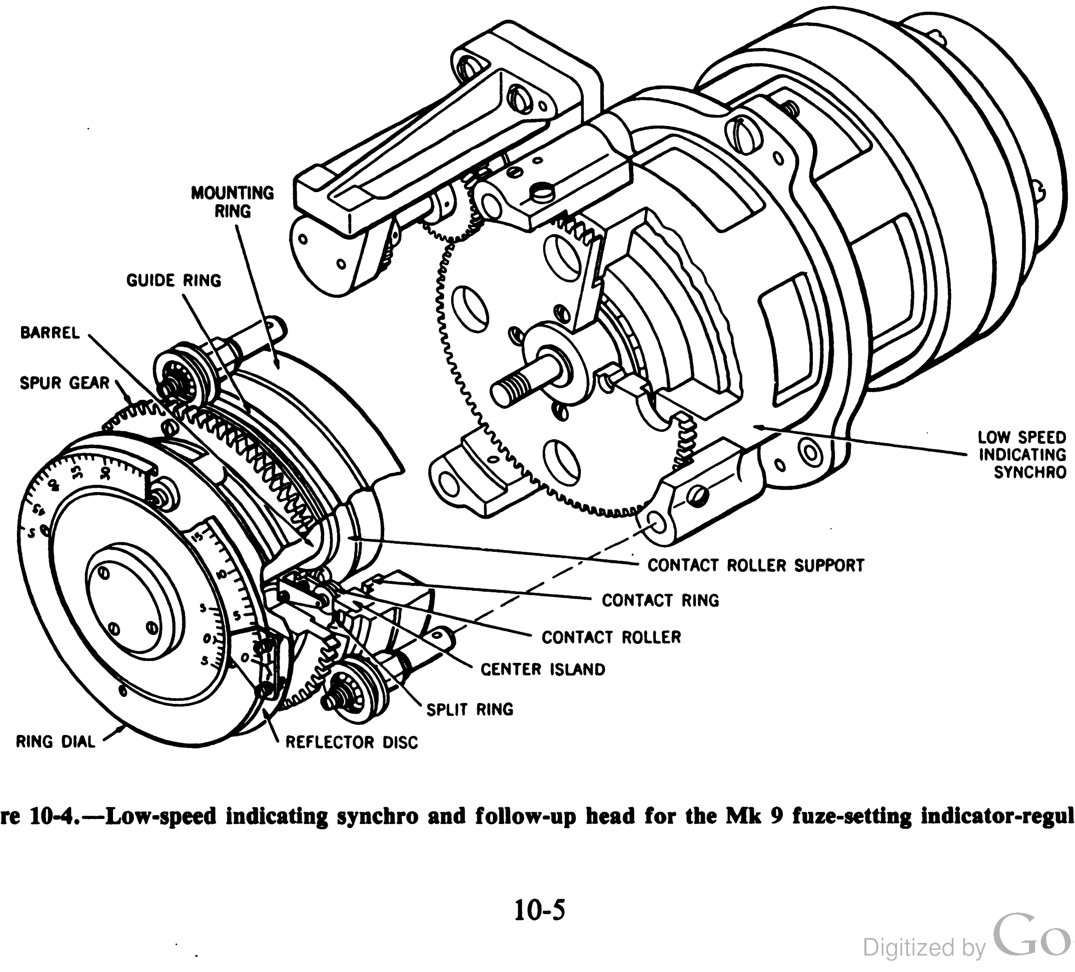
Indicating Section

The indicating section consists of a high-speed indicating synchro (TR), a low-speed indicating synchro (TRB), and the indicating dials. The high-speed TR receives fuze-setting orders at 180/7 speed. One revolution of the TR rotor corresponds to 2 seconds of fuze time. The rotor is attached to the pointer inner dial while the stator has a fixed mounting. This TR is used for indicating purposes only.

The low-speed TRB receives fuze-setting orders at 3.6/7 speed. One revolution of the TRB rotor corresponds to 100 seconds of fuze time. The rotor is attached to the inner dial of the zero-reader. The TRB stator is mounted on bearings and is driven by response at the same speed as the zero-reader ring dial, which is also driven by response. When the rotor is rotated by a signal, the rotation of the stator by the response to that signal will be in the opposite direction to that of the rotor.

The low-speed indicating TRB is used for both indicating and control purposes. This is made possible by the addition of a low-speed follow-up head (fig. 10-4), which under certain conditions that will be explained later, can control the fuze-setting power motor. The low speed follow-up head consists of two principal units—a mounting ring and a contact roller assembly.

The mounting ring is made of insulating material and is fixed in position. On its inner surface it supports two contact rings. The lower ring is continuous, but the upper ring is divided

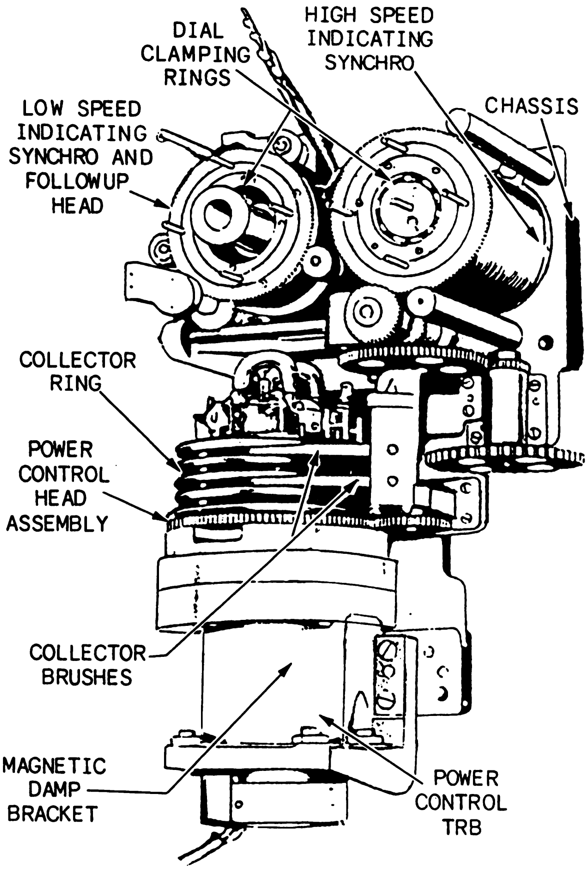


53.236

Figure 10-4.—Low-speed indicating synchro and follow-up head for the Mk 9 fuze-setting indicator-regulator.

into three segments separated from each other by small spaces. Two of these segments, called the split ring, cover nearly the entire circle; the third, called the center island, is only a few degrees wide. Four terminals, on the outer edge of the mounting ring, connect the lower contact ring and the three segments of the upper contact ring to the external circuits.

The contact roller assembly is mounted on, and rotates with, an insulating extension of the rotor shaft of the low-speed indicating TRB. It has two contact rollers, mounted on flexible arms, which are spring-extended to hold the rollers firmly in contact with the rings. Flexible wire shunts assure good connections between the main body of the assembly and the arms that carry the rollers. One of the rollers makes contact with the continuous lower ring; the other makes contact with the segmented upper ring. The particular segment that it contacts depends on the relative positions of the TRB rotor (fuze-setting order) and the zero-reader dial (existing fuze setting). When a roller is in contact with either segment of the split ring, it causes the power motor controller to energize the power motor. When the roller rests on the center island (which occurs when the difference between order and existing setting is small), it permits the power control head to energize the power motor. In each case the circuit within the head is from the continuous ring, through the roller assembly, and then to one of the segments of the split ring or to the center island.


DIAL CLAMPING RINGS
HIGH SPEED INDICATING SYNCHRO
CHASSIS
LOW SPEED INDICATING SYNCHRO AND FOLLOWUP HEAD
COLLECTOR RING
POWER CONTROL HEAD ASSEMBLY
COLLECTOR BRUSHES
MAGNETIC DAMP BRACKET
POWER CONTROL TRB

53.237

Figure 10-5.—Mk 9 fuze-setting indicator-regulator chassis assembly.

Q5. How are fuze orders transmitted to the fuze-setting mechanism?

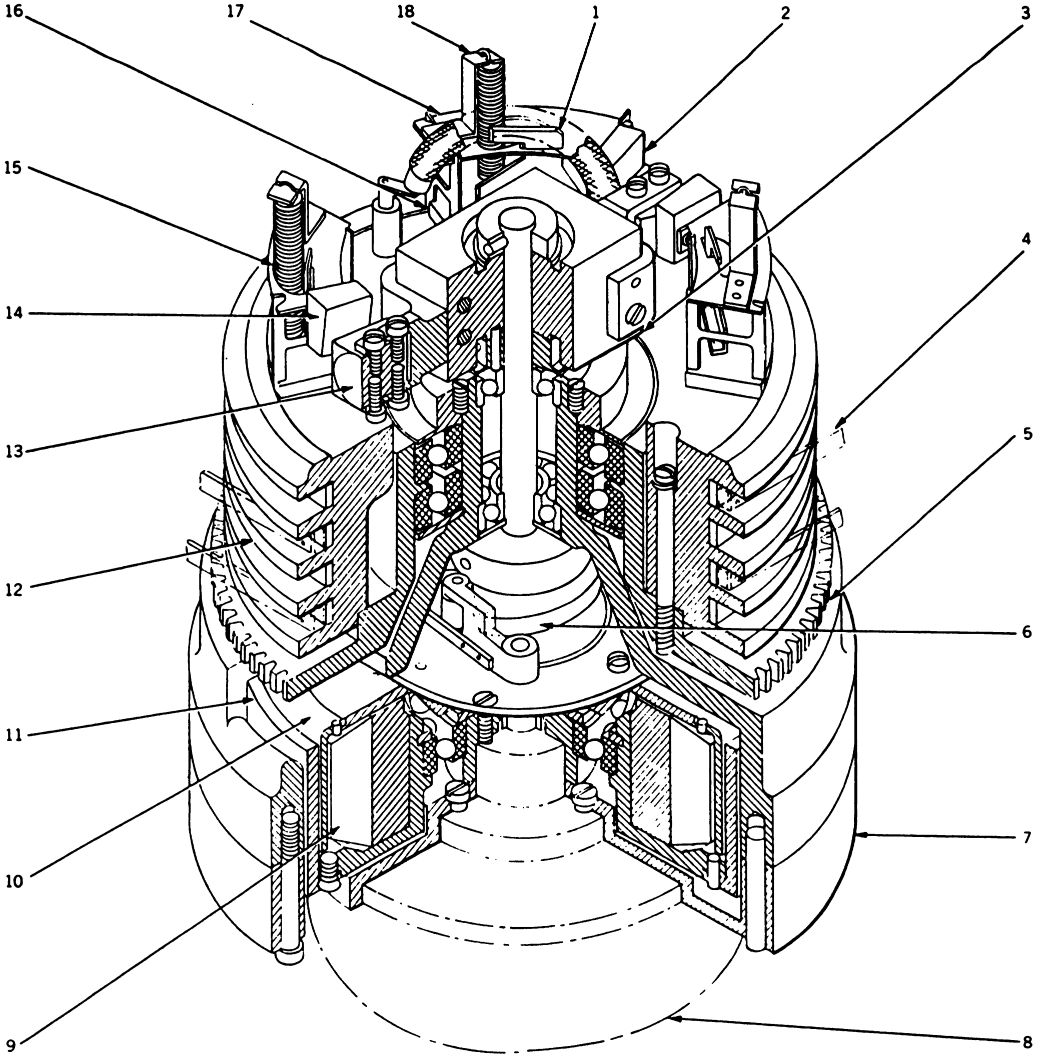
Q6. What two methods can be used to set the regulator?

Q7. How many revolutions of the TR corresponds to 2 seconds of fuze time?

Power Control Synchro (TRB) and Power Control Head

The power control synchro (TRB) and power control head (fig. 10-5) control the action of the main power motor only when the difference between fuze-setting order and existing fuze setting is small. The power control TRB rotates at the same speed (180/7) as the high-speed indicating TR, and receives its stator signal from the same source. The rotor is energized with 115-volts 60 hertz from a step-down transformer. One revolution of the power control TRB corresponds to 2 seconds of fuze time.

The power control head (fig. 10-6) compares the fuze-setting order, as received by the power control TRB, with the existing fuze setting, which is received automatically or mechanically through response gearing from the power motor. It acts through the power motor controller to cause the power motor to run in the direction necessary to set the fuze in accordance with the order. It also acts, through the controller at high or low torque, depending on the magnitude of the difference between the order and the existing setting.



LEGEND

1-STOP
2-OUTER CONTACT
3-INNER CONTACT SUPPORT
4-BRUSH
5-RESPONSE INPUT GEAR
6-DRIVING CAM ASSEMBLY
7-MOUNTING BRACKET
8-CONTROL SYNCHRO
9-MAGNETIC DAMP ASSEMBLY
10-COPPER DRUM (SHIELD)
11-FIELD RING
12-COLLECTOR RING ASSEMBLY
13-INNER CONTACT
14-OUTER CONTACT
15-CONTACT SUPPORT SPRING
16-H-SHAPED SPRING PLATE
17-OUTER CONTACT SUPPORT
18-VERTICAL ARM

53.238

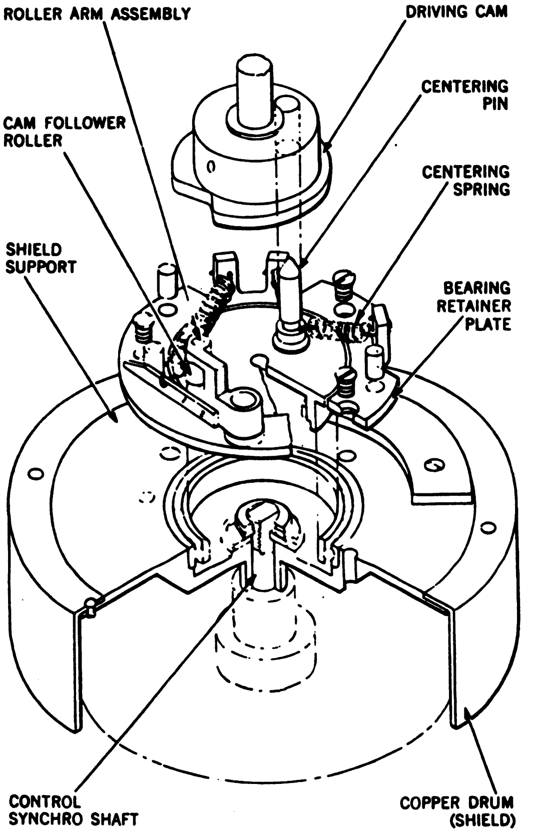
Figure 10-6.—Power control head.

The power control head consists of five groups of parts, arranged so that they can rotate with respect to each other or with respect to the synchro housing. These groups are as follows:

1. Magnetic damp assembly
2. Driving cam assembly
3. Collector ring assembly and response input gear
4. Outer contacts and supports
5. Inner contact and supports

MAGNETIC DAMP ASSEMBLY.—One part of the magnetic damp assembly consists of a circular permanent magnet and support mounted on ball bearings so that they are free to rotate independently of the synchro housing and of all the other units of the follow-up head. A copper drum, mounted on the driving cam assembly, forms the other member of the damp assembly. The driving cam assembly is secured to the synchro rotor; the copper drum, therefore, rotates with the synchro shaft. Drum rotation sets up eddy currents that tend to cause rotation of the magnet. The inertia of the magnet keeps rotating after the shaft rotation has ceased and induced currents create a torque that tends to carry the drum along with the magnet. The result is a flywheel action that produces smoother operation.

DRIVING CAM ASSEMBLY.—The driving cam assembly (fig. 10-7) permits the inner and outer contacts to come together without shock. It does this by providing a temporary and controlled amount of lost motion between the TRB shaft and the inner contacts, which are positioned by the TRB shaft. As shown in figure 10-7, the driving cam is mounted on a centering pin which, in turn, is mounted on an inner plate that is free to rotate with respect to the TRB shaft. The centering pin is attached by two spring lugs on the bearing retainer plate, which is screwed to the shield support and, therefore, rotates with the TRB shaft. A roller arm assembly is also mounted on the bearing retainer plate with a spring that holds its roller in the bottom of the cam notch.



53.239

Figure 10-7.—Driving cam assembly (exploded view).

The driving cam has a shaft extending upward to carry the inner contacts. At the start of movement, when a signal is first received, the centering pin springs cause the cam to rotate with the TRB shaft. However, as soon as an inner contact meets an outer contact, the cam tends to resist further rotation until response speed overtakes the TRB shaft speed. During this interval, one centering spring is compressed and the other is extended. At the same time, the cam follower roller is driven up one side or the other of the cam notch. When the TRB and response speed become equal, or when the setting becomes matched to a stationary signal, the centering springs return the cam to the normal position where it is exactly centered by the cam follower returning to the bottom of the cam notch.

COLLECTOR RING ASSEMBLY AND RESPONSE INPUT GEAR.—The collector ring assembly (shown in figure 10-6) is the unit through which connections are made from the rotating power control head to the power motor controller. (The power motor controller is mounted down in the ammunition handling room.) The collector ring assembly is mounted and secured to the response input gear, and carries, on its upper surface, a set of four outer contacts. The response input gear is driven by the output of the power motor so the position of all these units is directly proportional to the existing fuze setting.

ANSWERS TO QUESTIONS Q5 THROUGH Q7.

A5. Mechanically.

A6. Either manual or automatic control.

A7. One.

Four collector rings are mounted in channels in the outer surface of the insulating body of the assembly. These rings are connected by means of brushes to the circuit of the power motor controller so that uninterrupted continuity is maintained regardless of rotation. The rings are connected internally to terminals in the upper surface of the body for connection to the outer and inner contacts.

Q8. One revolution of the power control TRB corresponds to how many seconds of fuze time?

Q9. In the magnetic damp assembly, what sets up the eddy current that causes rotation of the magnet?

Q10. Through what unit is the connection made from the rotating power control head to the power motor controller?

OUTER CONTACTS AND SUPPORTS.—Four outer contacts are mounted on flexible supports on the upper surface of the collector ring. These contacts are connected in two pairs: each pair is connected to a slipring. The flexible mounting permits some displacement of the outer contacts by the inner contacts.

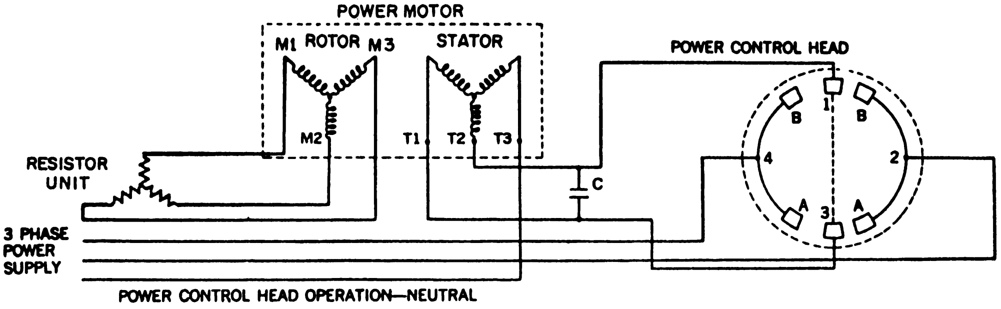
INNER CONTACTS AND SUPPORTS.—The inner contacts are mounted on a support that is positioned by the driving cam shaft. Its position is, therefore, indirectly determined by the TRB shaft position. There are two inner contacts, insulated from each other and from the shaft by the support. They are connected, through flexible leads, to the remaining two collector rings. Since there are never more than a few degrees of difference between the positions of the collector ring assembly and the inner contacts, the flexible leads provide sufficient freedom of movement.

Principle of Operation of the Power Control Head

The power control head operation is illustrated by schematic drawings in the next three figures.

NEUTRAL OPERATION.—Figure 10-8 (neutral position) employs six contacts connected so there are four points of electrical connection. Inner contacts 1 and 3 have a common support and are rotated together by the power control TRB. It should be kept in mind however, when studying these diagrams, that contacts 1 and 3 are not electrically connected to each other. Contacts 2A, 2B, 4A, and 4B are rotated together by the response of the power motor. They always rotate in such direction as to follow contacts 1 and 3 and, therefore, the signal. Thus, the power control head is an error-detecting device that compares the signal with the existing fuze setting.

LOW-TORQUE OPERATION.—Through use of the power control head, two steps of torque



53.240

Figure 10-8.—Power control head operation (neutral).

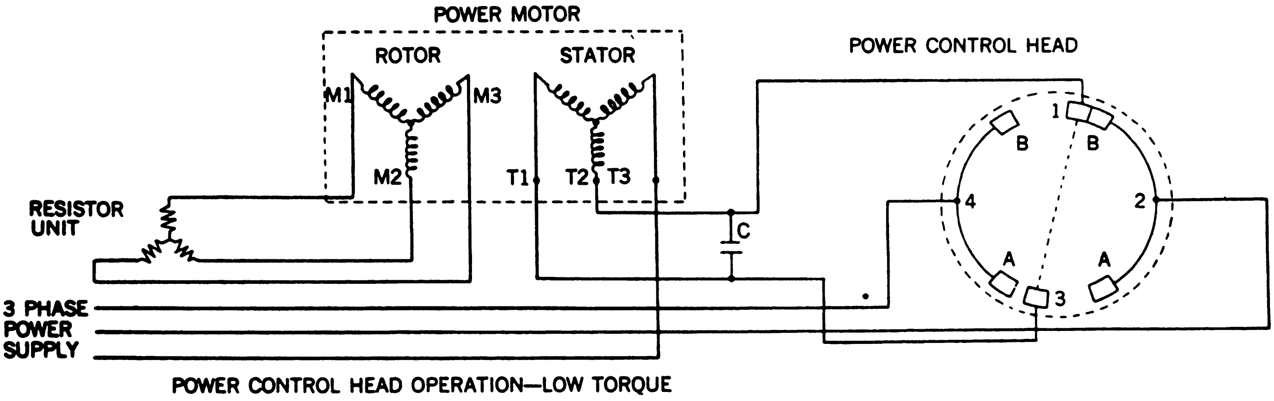
(low and high) are available. Figure 10-9 shows the circuit conditions with the signal in a clockwise rotation and where low torque only is required to follow within the limits of the contact setting. Under these conditions, contacts 1 and 2B are closed. Closing these contacts energizes the power motor by putting line voltage across T2-T3 of the stator and energizes the T1 leg of the motor through condenser C. The motor is connected across only one phase of the power supply. The effect of the condenser is to produce a time phase difference between the electric currents in the stator winding of the power motor so that a rotating magnetic field is obtained. It is the rotation of this field that causes the power motor to rotate. When reversing the signal, the sequence of operation is counterclockwise to the rotation.

In both the above cases, the motor operates as a capacitor start, capacitor run, single-phase motor which produces sufficient torque to synchronize with the signal when the change in fuze setting required is small.

HIGH-TORQUE OPERATION.—The torque required of the power motor will be greater under some conditions than that which was illustrated earlier. Under such conditions, response will begin to lag behind the demand of the signal until contacts 3 and 4A close, as shown in figure 10-10. In this case, the power motor is connected directly across the three-phase line and the maximum available torque of the motor is obtained. As in low-torque operation, a reversal of signal demand would reverse the line connections to T1 and T2 through the power control head rotation of the power motor. Condenser C remains across one phase of the power motor during three-phase operation, but has no appreciable effect on the motor operation.

The operation of a three-phase motor from a single-phase line, as described in low-torque operation, is known as split-phase operation. The torque available under this condition of operation may be varied, within limits, to suit a particular installation by varying the value of condenser C. This will permit adjusting the low-torque operation of the system without affecting the high-torque operation. Normally, however, no adjustment is required.

Q11. How many contacts make up the four connections of the power control head?



53.241

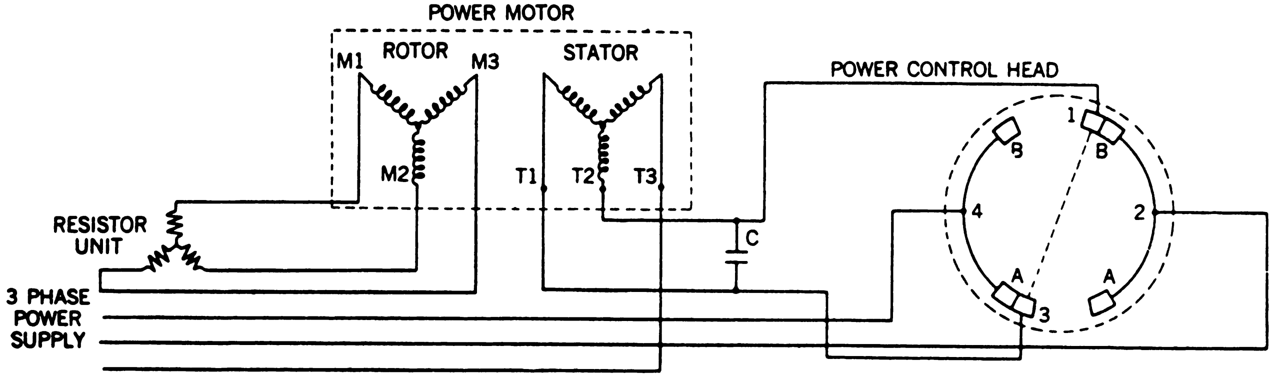
Figure 10-9.—Power control head operation (low torque).

ANSWERS TO QUESTIONS Q8 THROUGH Q10.

A8. Two seconds.

A9. Drum rotation.

A10. The collector ring assembly.



53.242

Figure 10-10.—Power control head operation (high torque).

Q12. In low torque operation, what is the purpose of the condenser?

Operating Under Control of the Low-Speed Indicating TRB and Follow-Up Head

Operation of the regulator system can be controlled through either the power control TRB or the low-speed indicating TRB. As previously explained, the power control TRB controls the system when the difference between fuze setting is small. In this respect, it can be compared to the fire control for the 5"/38 hydraulic power drive as described in chapter 6. Likewise, regulator control under the low-speed indicating and follow-up head can be compared to the TRB coarse control, also described in that chapter.

The low-speed indicating TRB controls the system only when it is synchronizing to an advanced signal, or to bring the system back into synchronism when the power motor has followed the signal to the electrical limit of the limit-stop mechanism. The low-speed indicating TRB receives the fuze-setting order at 3.6/7 speed, whereas the control synchro receives it at 180/7 speed. As explained earlier, one revolution of the power control head is equivalent to 2 seconds fuze time. If this were the only control head in the regulator, the existing fuze setting apparently could be synchronized with the signal at any one of several values by multiples of 2 seconds. The low-speed follow-up head eliminates this possibility.

The low-speed indicating TRB rotor rotates the contact roller assembly of the low-speed follow-up head. One revolution of the contact roller is equivalent to 100 seconds of fuze time. As was noted in the description of the low-speed indicating TRB, the stator of the low-speed indicating TRB is rotated by response in a direction opposite to that which the signal rotates the rotor. Since rotation of the stator causes the rotor to follow its motion, any difference between the signal and the existing fuze setting will cause the rotor and the contact roller assembly to be displaced from their neutral position through an angle corresponding to the error.

The roller in the low-speed follow-up head normally rests on the center island. However, if the roller moves to one of the split rings, it breaks the circuit through which the synchro cutout relay and the controller cutout relay are energized. When the synchro output relay is deenergized, the stator circuit to the power control TRB is broken, preventing the latter from receiving the signal. When the controller cutout relay is deenergized, it breaks the 440-volt supply to the power control head, preventing the latter from deenergizing the power motor. Thus, when the roller moves off the center island, control of the power motor is taken away from the power control head.

The regulator must now synchronize to an advanced signal (for example, 30 seconds away) in the direction for increased fuze time. The roller low-speed head will no longer rest on the center island, but will rest on a split ring and will take the power motor control away from the power control head, as described earlier. A 115-volt control circuit is now completed through the low-speed head, an increase limit switch, an increase following relay, a decrease following relay, and the controller cutout relay. The increase following relay is energized and closes the contacts that connect T1 and T2 of the power motor to the power contactor. Since T3 is connected permanently to the contactor, the power motor is connected directly across the 440-volt line and operates to overtake the signal with maximum torque. When the contact roller returns to the center island, the increase following relay is deenergized and the synchro cutout relay is energized. The power control head once again takes over control of the power motor.

If the signal were for decreased fuze time, the contact roller would rest on the other split ring. The decrease following relay would be energized through the decrease limit switch. The connections required for increased fuze time, and the motor, would rotate in the reverse direction.

Another function of the low-speed head is to bring the system back into synchronism when the power motor has followed the signal to the limit of the limit-stop mechanism. Assume now that the signal has traveled beyond the lowest fuze-setting time set on the limit-stop mechanism. The power motor then drives the limit-stop traveling nut into the decrease limit switches. The first decrease limit switch breaks the 115-volt control circuit to the synchro cutout relay and the controller cutout relay, which are then deenergized. This, in turn, deenergizes the power control head in the manner previously mentioned. The second decrease limit switch breaks the circuit from the decrease split ring of the low-speed head, which would otherwise energize the power motor. The limit-stop mechanism thus acts, not only as a mechanical stop, but also deenergizes the regulator from further decreasing fuse-setting signals. The limit-stop mechanism itself will be described in more detail later.

If a signal for increasing the fuze setting is now received, the power control head cannot energize the power motor because of the open limit switches. The roller of the low-speed head, therefore, rolls onto the increase split ring. Since the increase limit switches are closed, the power motor is energized and the limit-stop traveling nut is driven away from the stop. This permits the decrease limit switches to reclose, and the power control head can then take over control of the power motor as soon as the signal is overtaken.

Limit-Stop Mechanism

The limit-stop mechanism is of the traveling-nut type. It prevents the regulator from operating (in either automatic or manual) beyond the limits of the fuze setting. When either the upper or lower limit of the fuze setting has been reached, the mechanism opens a limit switch which deenergizes a relay in the power motor controller and thereby breaks the supply circuit to the power motor. It also acts as a positive stop to the transmission gearing. Figure 10-11, a schematic sketch of the Mk 9 regulator's components, shows the limit-stop mechanism.

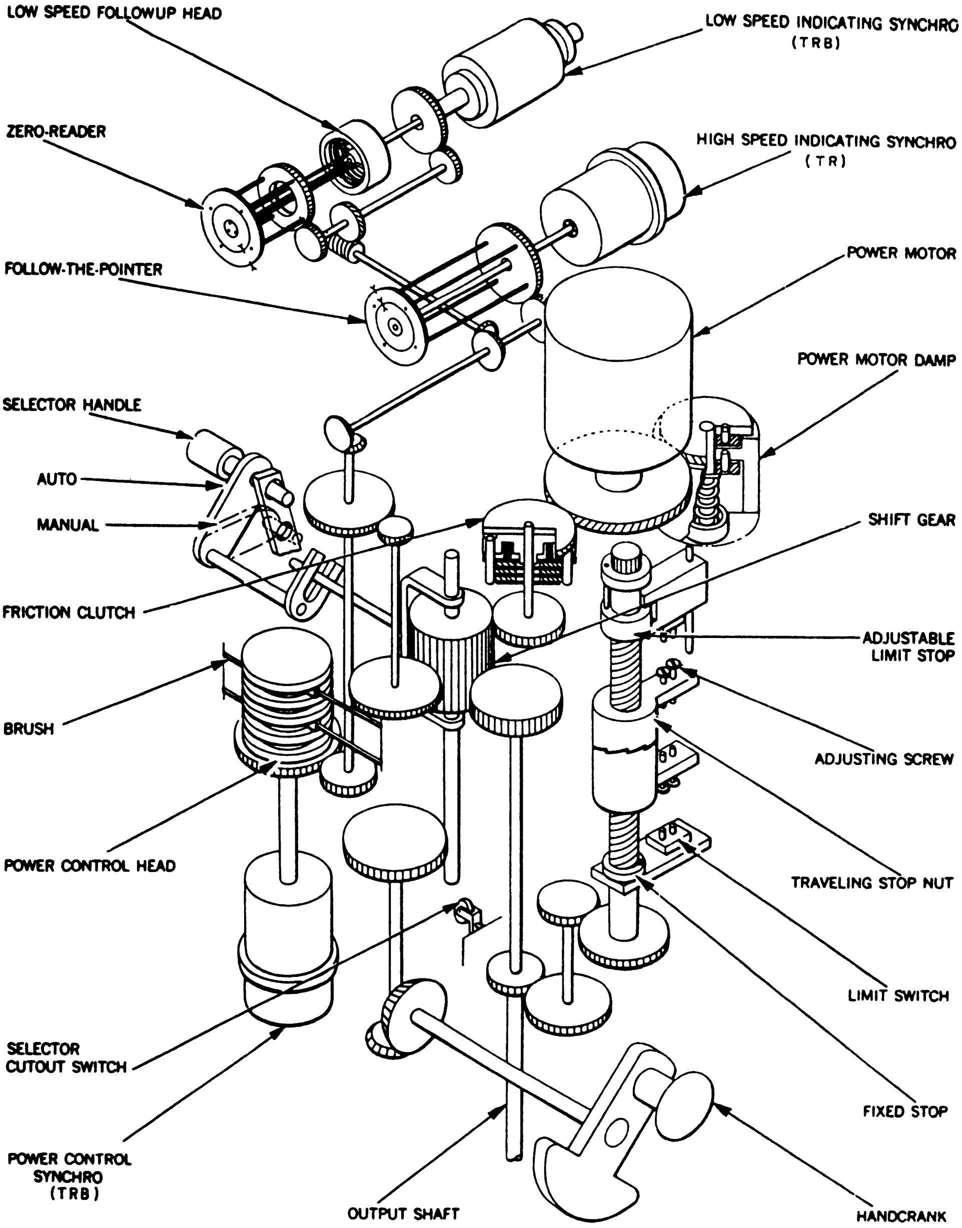
The traveling nut assembly of the limit-stop mechanism serves as a buffer at the mechanical limits of travel, in addition to providing the electrical and mechanical stopping action to which we previously referred. It does this by permitting some override of the driving motor and gearing while preventing this override from being transmitted to the fuze.

As figure 10-11 shows, two mechanical stops are mounted on the limit-stop shaft and rotate with it. The lower stop, which is not adjustable, sets the maximum limit of the fuze setting; the upper stop, which is adjustable, sets the minimum limit. A lug on the upper face of the lower stop engages a corresponding lug on the lower face of the splined sleeve when the maximum limit of the fuze setting has been reached. A similar lug on the lower face of the upper stop engages a lug on the upper end of the ratchet when the minimum limit has been reached. In either case, the friction disks in the traveling stop nut assembly slip sufficiently to permit some additional rotation, thus avoiding mechanical shock and damage to the gearing, but their break action prevents the movement from continuing too far.

ANSWERS TO QUESTIONS Q11 AND Q12.

A11. Six.

A12. To produce a time phase difference between the electric currents in the stator winding of the power motor.



53.243

Figure 10-11.—Mk 9 fuze-setting indicator-regulator (mechanical schematic).

In regulators of early manufacture, the limit-stop mechanism permitted a maximum setting of 48.75 seconds. This limit has been increased to 50.35 seconds in the newer regulators. The lower limit in either is adjustable from 0 to 5 seconds. You will need to check your current type commander's instructions for the minimum fuze-setting limits allowed for your ship.

There are two limit switches at each end of the limit-stop travel. Each is a single-pole, double throw unit, wired into the circuit as single-throw, normally closed switches. One switch at one end of the limit stop is in series with the switch at the other end of the limit stop. These switches are in series with the center island of the low-speed follow-up head in a circuit that energizes the synchro cutout relay in the regulator and the controller cutout relay in the controller. The opening of either of these relays, when the low-speed follow-up head roller is on the center island, deenergizes the power motor through the controller and also opens the stator circuit of the power control synchro so it cannot receive further fuze-setting signals.

Each of the other two limit switches is in series with a split ring of the low-speed follow-up head. The opening of one of these switches will, therefore, open the circuit through which the low-speed head causes the power motor to drive in the direction of the excessive signal, but will not open the circuit for the opposite direction of drive. If, therefore, an opposite signal is received, it will move the low-speed roller to the opposite split ring, and the power motor will then back the regulator out of its electrical limit automatically. This feature prevents the loss of time that would occur if it were necessary to back the regulator out of its limit by the use of manual drive.

Operating Precautions

The following precautions are important and must be rigidly observed to prevent damage to the regulator and to ensure its safe operation:

1. Before shifting the selector switch to AUTO, make certain that the signal is first matched to the manual control, as indicated by dials.

2. Before shifting to AUTO, make certain that there is a projectile in one of the hoists.

3. Before shifting to AUTO, make certain that the synchros are energized. If the synchros are not energized when the selector switch is at AUTO, the center contacts of the power control head are uncontrolled and the power motor may run away.

4. When the regulator is not in use, the selector switch should be in the MANUAL setting, and the power switch should be OFF.

WARNING: If any work is to be done on the regulator, tag out and secure the power at the controller, and avoid touching exposed or live wires

Q13. One revolution of the contact roller is equivalent to how many seconds of fuze time?

Q14. The limit-stop mechanism of the 5"/38 mount is of what type?

Q15. What is the first action that should be taken before shifting to AUTO on the 5"/38?

FUZE-SETTING EQUIPMENT FOR THE 5"/54 MK 42 MODS 9 AND 10 GUN MOUNTS

The Mk 29 fuze setter is a redesign of the old Mk 24 fuze setter used in the 5"/54 Mods 7 and 8. The redesign is almost 100 percent, except for the actuating mechanism (fuze pot extending and retracting mechanism). There are four modifications to this fuze setter; Mods 0 and 1 are used on the Mod 9 gun mounts, while Mods 2 and 3 are installed on the Mod 10 gun mounts. The differences between the mods are minor and will be pointed out as we proceed through this discussion.

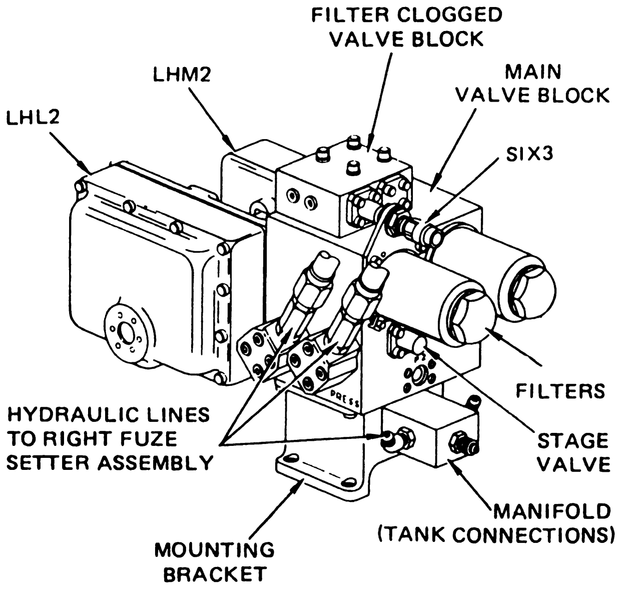
The Mk 29 Mods 2 and 3 fuze setters are hydraulically operated and electromechanically controlled. Our discussion will be directed to the right fuze setter. It consists of a solenoid valve and manifold (called a flow control valve manifold on the Mods 0 and 1 fuze setters), actuating mechanism and solenoid, fuze-setter assembly, and an amplifier (located in the EP2 panel).

SOLENOID VALVE AND MANIFOLD

The solenoid valve and manifold (fig. 10-12) is mounted on the rammer beam and controls the application of fluid to both fuze-setter assemblies. It consists of two solenoid housings (LHL2 and LHM2), a main valve block, a filter clogged valve block, and two filters. (Mods 1 and 0 fuze setters have only one filter.)

Solenoid Housings

The solenoid housings (LHL2 for the right fuze setter and LHM2 for the left fuze setter) contain solenoids that control the flow of fluid to the fuze-setter assemblies. Each housing


FILTER CLOGGED VALVE BLOCK
LHM2
MAIN VALVE BLOCK
LHL2
SIX3
FILTERS
HYDRAULIC LINES TO RIGHT FUZE SETTER ASSEMBLY
STAGE VALVE
MANIFOLD (TANK CONNECTIONS)
MOUNTING BRACKET

53.328

Figure 10-12.—Solenoid valve and manifold.

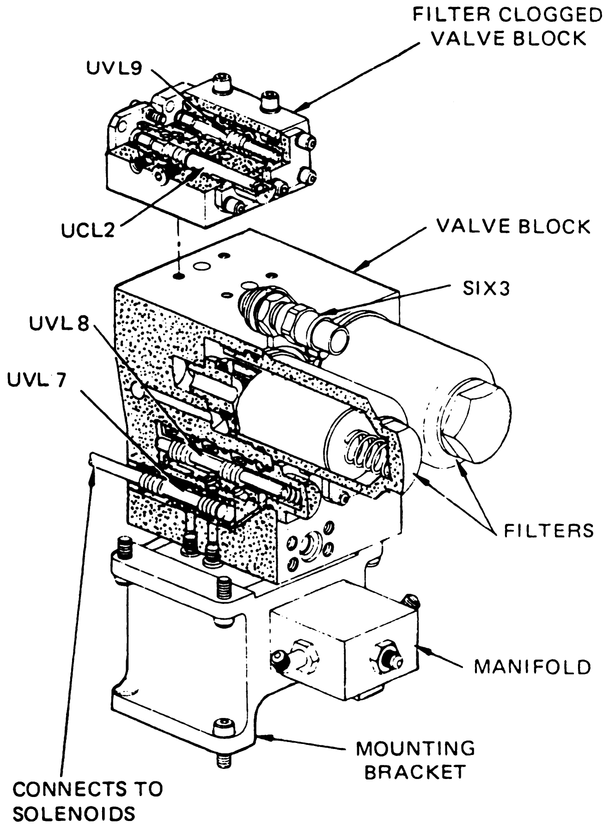
contains three solenoid coils (only two are used; the third is a back-up) and two solenoid position-indicating switches. A latch arm and plunger rod assembly connect solenoid LHL2-LC2 to solenoid valve UVL7 (fig. 10-13) in the main valve block. Solenoid LHL2-LC3 controls the operation of a detent, which locks the linkage of solenoid LHL2-LC2 in its energized position.

Fluid Filters

The two fluid filters remove impurities from the hydraulic fluid of the upper accumulator before it is ported to UVL7 in the valve block. The filter bowls screw into the threaded holes in the valve block and enclose the filter elements.

Filter Clogged Valve Block

The filter clogged valve block contains fluid filter bypass valve UVL9 and pressure switch piston UCL2. Valve UVL9 and piston UCL2 each have a two-land spring-loaded plunger. If the filters clog, UVL9 moves downward to bypass fluid and UCL2 moves downward to activate filters clogged switch SIX3. Switch SIX3 provides a fuze-setter filters clogged indication in the EP2 panel.



53.329

Figure 10-13.—Solenoid valve and manifold. Valve block.

Main Valve Block and Manifold

The main valve block contains two solenoid valves and two stage valves: one solenoid and stage valve pair functions for the right fuze-setter assembly and the other pair functions for the left fuze-setter assembly. One pair of valves is solenoid valve UVL7 and stage valve UVL8. Valve UVL7 has a two-land, two-position plunger mechanically positioned by solenoid LHL2-LC2 to port PA to stage valve UVL8. Solenoid LHL2-LC3 releases detent to allow the UVL7 plunger to spring-return to neutral and block PA to UVL8. Valve UVL8 has a two-land, spring-loaded plunger that applies PA to the fuze-setter assembly and is repositioned by spring pressure to block PA from the fuze-setter assembly.

Q16. How many modifications are there to the Mk 29 fuze setter?

Q17. On the Mk 42 gun system, where is the solenoid valve and manifold located?

Q18. Where is UVL9 located?

FUZE-SETTER ACTUATING MECHANISM AND SOLENOID

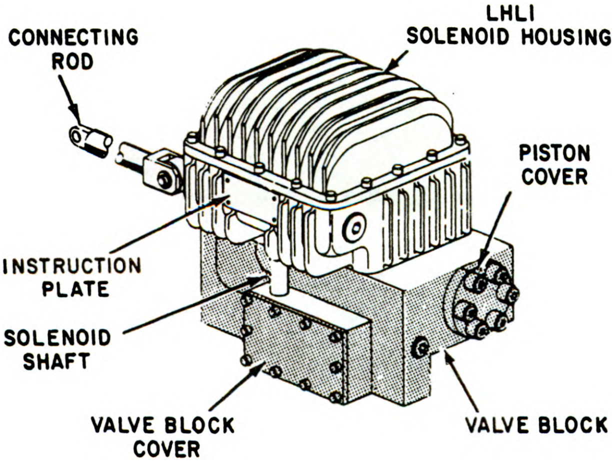
The right and left fuze-setter actuating mechanism (the right fuze-setter shown in figure 10-14) and solenoids, mounted on the slide, extend and retract the right and left fuze-setter assemblies. Each fuze-setter actuating mechanism and solenoid consists of a solenoid housing and a valve block, which contain similar components.

Solenoid Housing

The LHL1 solenoid housing contains two mechanically detented solenoid coils, LHL1-LC1 and LHL2-LC2; and a two-solenoid position indicating switch, LHL1-SI1. A solenoid shaft and a valve lever (fig. 10-15) connect the solenoids to UVL1 in the valve block.

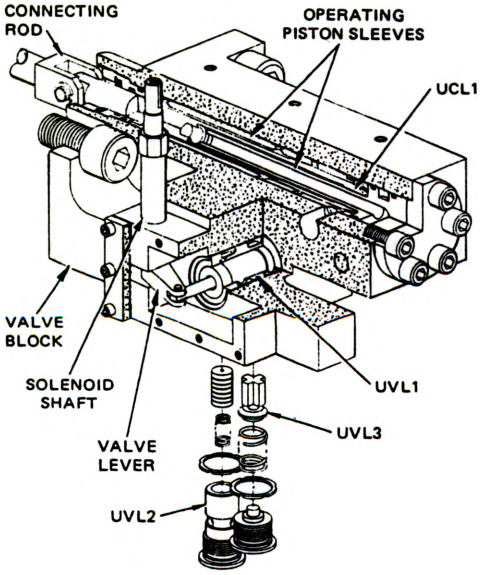
Valve Block

The valve block (fig. 10-15) contains the hydraulic components, which control the direction, speed, and travel of the fuze-setter assembly. The components in the valve block are the direction selector valve UVL1, flow control valve UVL2, check valve UVL3, and operating piston UCL1. Valve UVL1 has a two-land, two-position plunger mechanically positioned by solenoids LHL1-LC1 and -LC2. Shifting the plunger of UVL1 selects the direction of fluid flow to operating piston UCL1. Valve UVL2 has a single-land plunger that is spring-loaded to the open position. Excessive hydraulic pressure moves the plunger against the spring to close a variable exhaust port. Valve UVL3 maintains even



53.330

Figure 10-14.—Fuze-setter actuating mechanism and solenoid.



53.331

Figure 10-15.—Cutaway view of fuze-setter actuating mechanism and solenoid.

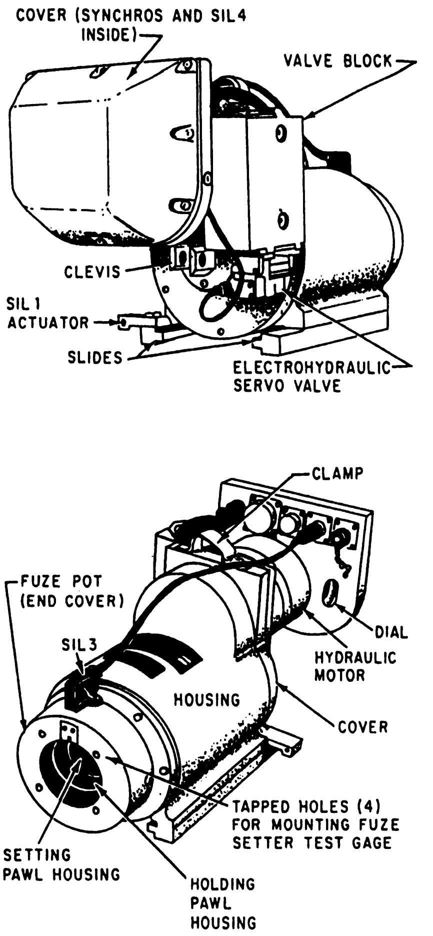
ANSWERS TO QUESTIONS Q13 THROUGH Q16.

A13. 100 seconds.

A14. Traveling-nut type.

A15. Ensure that the signal is matched to the manual control and dial indication.

A16. Four.



53.332

Figure 10-16.—Mk 29 fuze-setter assembly.

pressure between the head of UCL1 during extend and retract strokes to prevent a hydraulic block.

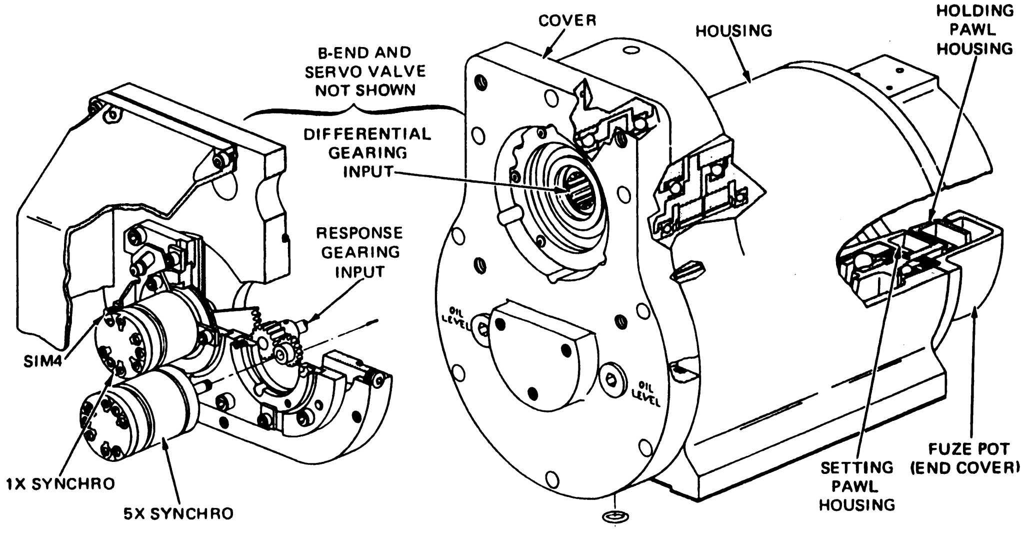
The hydraulic cylinder of the fuze-pot operating piston of UCL1 has a differential-area piston mounted on an inner sleeve and an outer sleeve. The operating piston of UCL1 extends and retracts the fuze-setter assembly. Two tapered grooves on each end of the piston head decelerate it at the end of the extend and retract strokes. A portion of the piston is hollow to form a cavity that fits onto the inner sleeve. The end of this cavity forms the large-area side of the piston UCL1; the rod end forms the small-area side. The rear area of piston UCL1 does not assist piston hydraulic operation.

FUZE-SETTER ASSEMBLY

The Mk 29 fuze-setter assembly (fig. 10-16) consists of a housing, a fuze pot, a hydraulic motor (B-end), a servo valve, synchros, and the gearing required to index and set the projectile's fuze. This assembly is not only smaller in size, lighter in weight, and less complicated than the one used on the old Mod 7 and 8 mounts, but it is mounted in such a manner that it can move fore and aft. Thus, the term "extend and retract fuze setter" is used when you refer to the Mk 29, rather than the term "extend and retract fuze pot."

Housing

The housing (fig. 10-17) encloses the fuze-pot and gearing. It provides a mounting surface for the hydraulic motor and servo valve.



53.333

Figure 10-17.— Fuze-setter assembly (exploded view).

Fuze Pot

The fuze pot is a round extension on the aft end of the housing. It has a cone-shaped opening that fits over the fuze on the nose of the projectile. Two spring-loaded pawls, that engage slots in the projectile uze, rotate within the fuze pot in response to index and fuze-set orders. An end cover encloses the end of the fuze pot and the actuator for the fuze setter engaged to projectile switch SIL3 (not shown).

Hydraulic Motor

The hydraulic motor is located on the forward end of the housing. The hydraulic motor rotates at 1,125 rpm during indexing. The differential gearing is connected to the motor drive shaft, which turns the holding and setting pawls to set the fuze. The gearing at the other end of the hydraulic motor shaft connects to a response gearing to drive the synchro (CT) rotors and indicator dial.

Servo Valve

The servo valve mounts on a valve block attached to the hydraulic motor. Signals from the fuze-setter amplifier to the servo valve control the porting of hydraulic fluid to the motor. Three flexible hoses connect the servo valve block to the solenoid valve and manifold. The servo valve converts an electrical input into a proportional hydraulic output that determines the direction and speed of the hydraulic motor.

Synchros

The synchros (CTs), mounted on a plate at the forward end of the hydraulic motor, receive fuze-order signals from the fire control system or the EP2 panel, and generate error signals that are applied to the fuze-setter amplifier. The synchros are connected to the hydraulic motor output shaft through the response gearing. One CT is 1-speed (1X), and the other is 5-speed (5X). The response gearing also drives an indicator dial to provide primary reading for fuze-setting time and for use with a fuze-setter test gage. A cover encloses the synchros and the plate.

Fuze-Setter Gearing

The fuze-setter assembly has two sets of gears driven by the hydraulic motor. A differential gearing in the fuze-setter housing rotates the setting and holding pawls; the response gearing rotates the CT rotors. During the index cycle, both pawls rotate to engage slots in the projectile fuze. During the fuze-set cycle, only the setting pawl rotates to position the fuze to the ordered position (fuze-set order). The gearing rotates the setting pawl clockwise for a decreasing fuze order or counterclockwise for an increasing fuze order. The response gearing rotates the rotors of CTs GCL1 and GCL3 to provide pawl position information to the fuze-setter servo loop. Response gearing rotation corresponds to differential gearing rotation to provide increasing or decreasing order response to the CT rotors. This response is actual pawl position. When it corresponds to the ordered position, it nullifies the CT (no error exists) and the fuze is set to the fuze order.

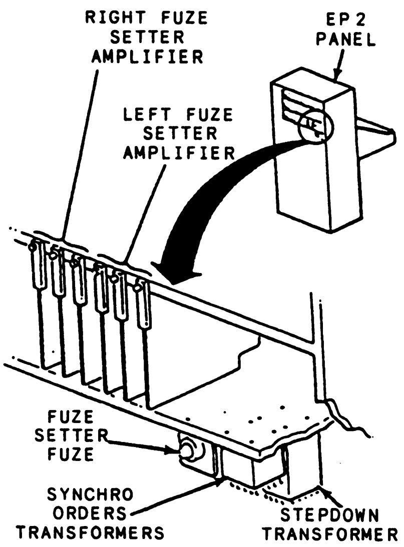
Q19. What connects UVL1 to its solenoid LHL1?

Q20. What is the speed of the hydraulic motor during indexing?

ANSWERS TO QUESTIONS Q17 AND Q18.

A17. On the rammer beam.

A18. In the filter clogged valve block.


RIGHT FUZE SETTER AMPLIFIER
EP2 PANEL
LEFT FUZE SETTER AMPLIFIER
FUZE SETTER FUZE
SYNCHRO ORDERS TRANSFORMERS
STEPDOWN TRANSFORMER

53.309

Figure 10-18.—Fuze-setter amplifier, Mk 42.

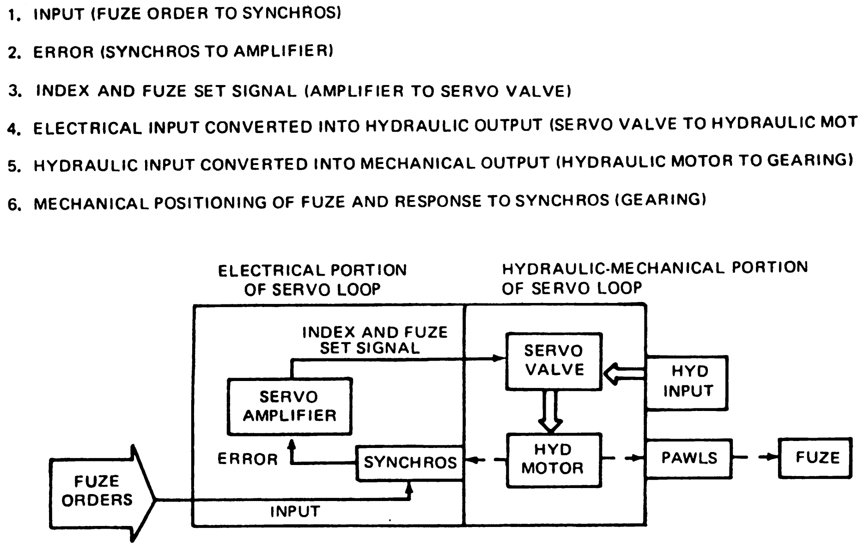
FUZE-SETTER AMPLIFIER, MK 42 GUN SYSTEM

The fuze-setter amplifier, mounted on a card rack housing in the EP2 panel (fig. 10-18), converts and amplifies signals from the CTs. The resulting signals activate the servo valve, causing the hydraulic motor to rotate and set the fuze. The fuze-setter amplifier contains six printed circuit (PC) boards, three identical boards for each fuze setter. A fuze, four control transformers (in a common housing), and a stepdown transformer (common to both amplifiers) are mounted below the PC boards. Two synchro order transformers (safe-set synchros) (not shown) are mounted inside the EP2 panel front door.

In addition to the fuze-setter amplifier, the EP2 panel contains other fuze-setter related components including a fuze-setter test plate, PA to fuze-setter hour counters, fuze-setter cycle test switches, fuze-setter logic input switch status indicators, and solenoid driver status indicators. These EP2 panel components are used to check, test, and troubleshoot the fuze-setter components.

INDEX AND FUZE-SET CYCLES

The hydraulic-mechanical operation for the index and fuze-set cycles is performed by the fuze-setter assembly. The fuze-setting operation is a servo loop that operates on error as shown in the signal flow diagram of figure 10-19. The error, determined by the CTs, is the difference between the fuze-order input and the angular position of the recessed slots of the fuze. The servo valve and the hydraulic motor and gearing perform the


1. INPUT (FUZE ORDER TO SYNCHROS)
2. ERROR (SYNCHROS TO AMPLIFIER)
3. INDEX AND FUZE SET SIGNAL (AMPLIFIER TO SERVO VALVE)
4. ELECTRICAL INPUT CONVERTED INTO HYDRAULIC OUTPUT (SERVO VALVE TO HYDRAULIC MOTOR)
5. HYDRAULIC INPUT CONVERTED INTO MECHANICAL OUTPUT (HYDRAULIC MOTOR TO GEARING)
6. MECHANICAL POSITIONING OF FUZE AND RESPONSE TO SYNCHROS (GEARING)
ELECTRICAL PORTION OF SERVO LOOP
HYDRAULIC-MECHANICAL PORTION OF SERVO LOOP
INDEX AND FUZE SET SIGNAL
SERVO AMPLIFIER
SERVO VALVE
HYD INPUT
ERROR
SYNCHROS
HYD MOTOR
PAWLS
FUZE
FUZE ORDERS
INPUT

53.334

Figure 10-19.—Index and fuze set servo loop.

fuze-setting operation; their hydraulic-mechanical operation in the servo loop (fig. 10-20) includes:

1. Conversion of electrical input into hydraulic output.
2. Conversion of hydraulic input into mechanical output through the hydraulic motor and gearing.

The servo valve controls the porting of PA to hydraulic motor UML1. The amplifier input to force motor BCL1 results in positioning the plunger of the flow control valve UVL4. The force motor coils and orifices UOL1 and UOL2 control the position of the UVL4 plunger; which, in turn, controls the directional rotation and speed of UML1. Orifices UOL3 and UOL4 create a pressure drop, which reduces the impact force of PA on plunger UVL4. Hydraulic motor UML1 converts the porting of PA from plunger UVL4 into mechanical rotary motion that drives the fuze-setter gearing. One end of the motor output drives the differential gearing and the other drives the response gearing. The differential gearing controls pawl movement and the response gearing controls CT rotor movement.

Fuze orders from the FCS (remote) or the EP2 panel (local-SAFE SET only) are applied to synchros (CXs) GCL1 and GCL3. The CXs compare the order to the fuze position and generate an error signal to the fuze-setter amplifier. The error is processed in the amplifier and the result is a generated signal for the index and fuze-set cycles to the force motor coils of BCL1. The coils of BCL1, through a flapper, cause a hydraulic imbalance which results in positioning the plunger of UVL4. The amplitude and polarity of the input to BCL1 determines the movement of the UVL4 plunger and the porting to hydraulic motor UML1 for an increasing or a decreasing order fuze setting.

For the index cycle, the order and the operation are always the same. Both pawls rotate to engage the slots in the fuze. Engagement of the setting pawl is designed to *always* rotate counterclockwise; the holding pawl *always* rotates clockwise. Easement cuts in the fuze aid pawl entry into the slots on the fuze. Friction between the pawls and the fuze determines which pawl rotates first. At the end of the index cycle, both pawls are engaged into their respective slots in the fuze, the fuze set cycle is ready to begin.

For the first fuze-set cycle, the amplitude and polarity of the input to BCL1 determines the rotation of the setting pawl; the holding pawl remains stationary and serves as a reference point for setting pawl movement. The setting pawl rotates counterclockwise for an increasing fuze-setting order and clockwise for a decreasing order. Minimum fuze setting is 0 through 5 fuze-seconds (adjustable) with a switch controlled lockout below 0.8 fuze-second.

The differential gearing reduces the 5-speed output of the hydraulic motor to 1-speed at the pawls. During the index cycle, the differential gears rotate both pawls, but in opposite directions: the setting pawl moves counterclockwise and the holding pawl moves clockwise. At the end of the index cycle, the gearing moves only the setting pawl counterclockwise for an increasing order and counterclockwise for a decreasing order. The response gearing output shaft drives the CT rotors: the 1X CT is driven at 1-speed (1X) and the 5X CT at 5-speed (5X). The gear at the 1X CT has a fuze-setting dial and a cam. The cam actuates SIL4 to indicate minimum fuze setting.

The fuze-setter assembly has two pawls, a holding pawl and a setting pawl. The projectile is fuze set by engaging the fuze-setter pawls with slots in the projectile fuze and then rotating the setting pawl to the desired fuze setting. The pawls are spring-loaded and engage the slots through easement cuts on the projectile.

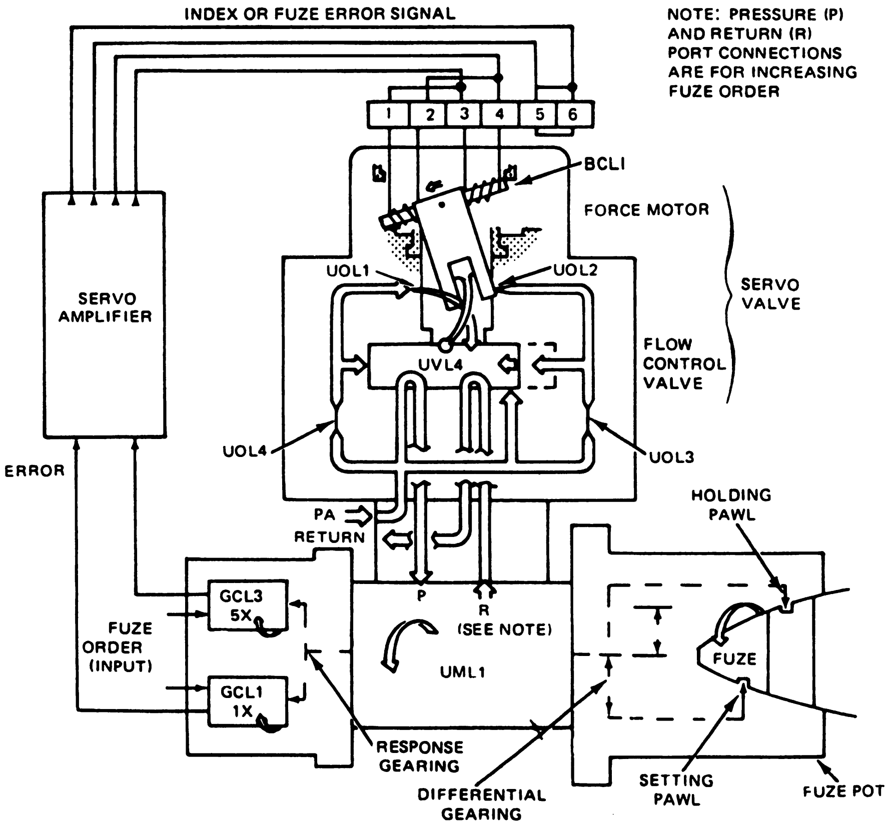
As each round is placed in the transfer tray, the relative positions of the slots and pawls change. Since there is no way of knowing where the slots of the fuze may be in relation to the pawls, there is no reference from which to start setting the fuze. At one time the pawls may engage the slots when the fuze setter is extended; at another time it may require a full turn clockwise by the holding pawl and a full turn

ANSWERS TO QUESTIONS Q19 AND Q20.

A19. A solenoid shaft and valve lever.

A20. 1,125 rpm.

1. FUZE ORDER IS ELECTRICAL INPUT TO SYNCHROS; SYNCHROS GENERATE ERROR SIGNAL TO AMPLIFIER.
2. INDEX AND FUZE SET SIGNAL TO FORCE MOTOR CLOSES UOL2 AND CAUSES A PRESSURE DROP AT UOL1.
3. PRESSURE INCREASE AT UOL2 INCREASES PRESSURE ON RIGHT SIDE OF UVL4 TO SHIFT IT TO THE LEFT.
4. UVL4 TO LEFT OPENS PRESSURE AND RETURN PORTS BETWEEN UVL4 AND HYDRAULIC MOTOR.
5. HYDRAULIC MOTOR ROTATION DRIVES DIFFERENTIAL AND RESPONSE GEARING.
6. GEARING ROTATES SETTING PAWL AND RESPONSE TO SYNCHROS (ACTUAL PAWL POSITION).



53.335

Figure 10-20.—Hydraulic-mechanical operation in index and fuze set servo loop.

counterclockwise by the setting pawl before engagement. Indexing ensures both a reference point and positive engagement of the pawls in the slots.

The pawls are rotated through a differential (sun) gear driven by the B-end. As a result of the gearing, the direction of rotation of the pawls is fixed during and after the indexing cycle. During the indexing cycle, the setting pawl rotates counterclockwise and the holding pawl rotates clockwise. When indexing is complete, the holding pawl does not move but the setting pawl (and the fuze) can be rotated in either direction. The pawls do not rotate simultaneously. Only one pawl can rotate at a time. The 400-hertz indexing voltage is supplied from a secondary winding of transformer TPL1 in the power supply.

Internal friction of the unit determines which pawl turns first. When the fuze setter is retracted, the pawl with the least resistance turns in response to the fuze-order signal. When the fuze setter is extended, and before either pawl is engaged, the pawl with the least resistance turns until it engages its slot and then it stops. If the holding pawl turns first (clockwise), it stops when it engages the holding slot. Motion is then transferred (through the differential gearing) to the setting pawl and it rotates counterclockwise to complete the indexing cycle. If the setting pawl rotates first (counterclockwise), it stops when it engages the setting slot (due to projectile fuze torque). Motion is then transferred to the holding pawl which rotates (clockwise) until it engages its slot and stops. Motion is again transferred to the setting pawl, and it rotates the fuze (counterclockwise) to complete the indexing cycle.

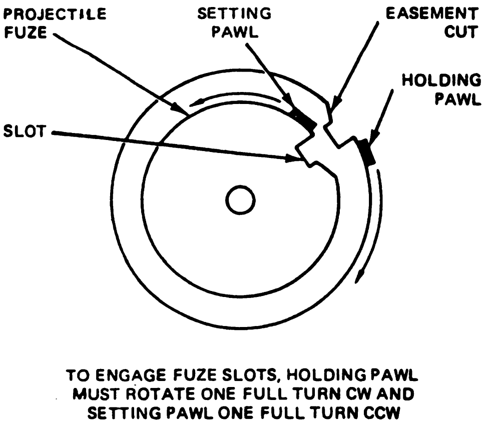
Q21. What controls porting of PA to hydraulic motor UML1?

Q22. What determines which pawl will rotate first?

Q23. How many pawls does the fuze-setter assembly have?

INDEX CYCLE

Under maximum misalignment conditions (fig. 10-21), each pawl requires one (1) full turn before it engages a slot. To ensure pawl engagement during the indexing cycle, 2-1/2 turns of the pawls are needed; that is, one pawl may turn once and the other rotate 1-1/2 turns, or any combination thereof. (These turns are referred to as dead turns, since the fuze is not being set, although it is being turned.) The extra one-half turn is provided to ensure that at least two (2) turns are made and is accomplished by displacing either pawl one-half turn from the other immediately after the fuze setter is retracted. The direction of displacement is always toward a lower fuze-time setting.



TO ENGAGE FUZE SLOTS, HOLDING PAWL MUST ROTATE ONE FULL TURN CW AND SETTING PAWL ONE FULL TURN CCW

53.336

Figure 10-21.—Fuze-setter pawls at maximum misalignment.

NOTE: The 10-degree relative pawl position selected for the following examples is for illustrative purposes only. Actually the fuze order is always applied to the CTs. The fuze order is variable and can be any value up to and including 45 fuze-seconds. However, the signal is not applied to the fuze-setter amplifier during indexing.

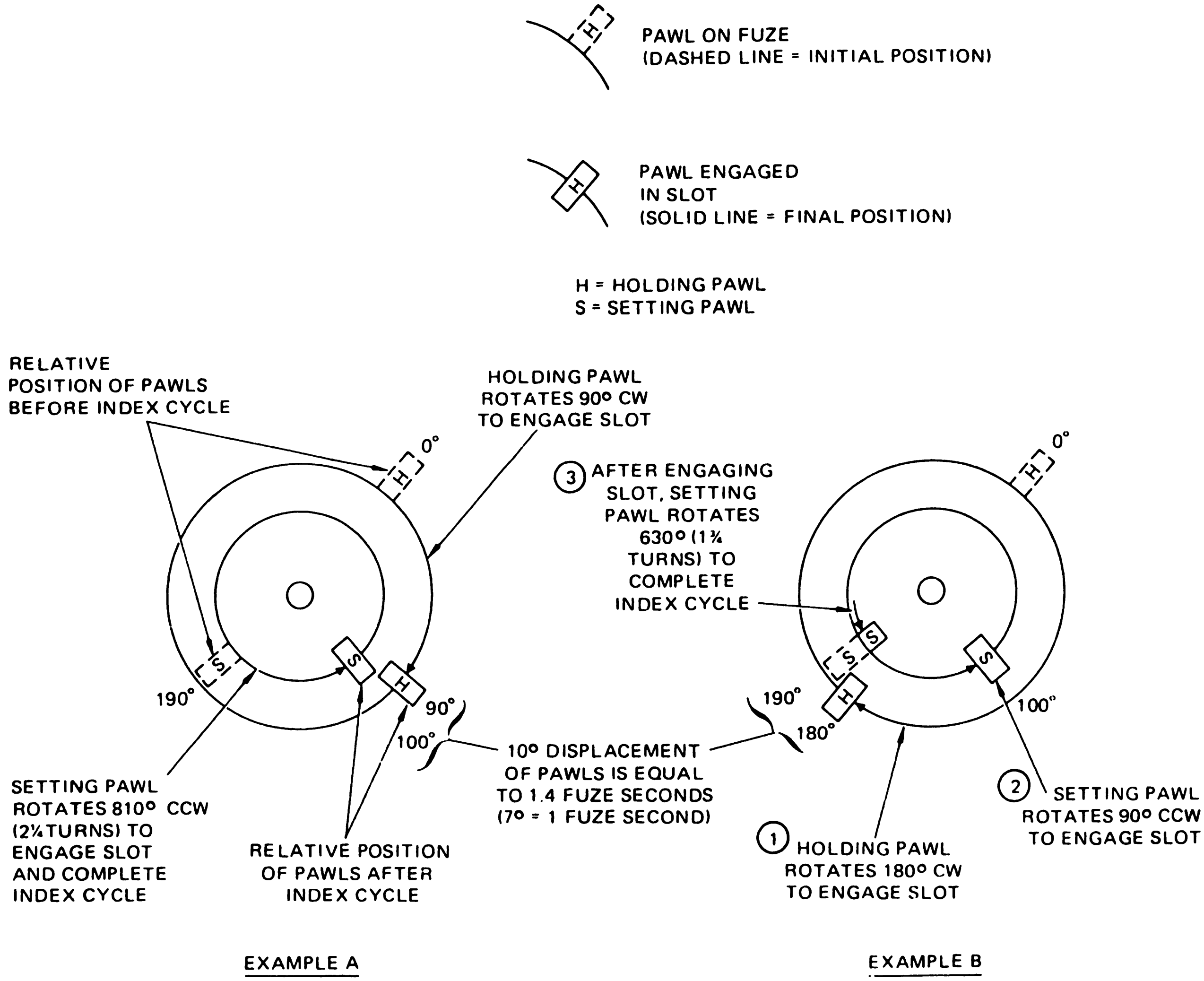
NOTE: Seven degrees of angular rotation is equal to one (1) second of fuze time on a Mk 342 fuze; newer fuzes such as the Mk 393 have different fuze times.

The relative position of one pawl to the other (angular difference) is used as a reference. So long as this difference, whatever it may be, can be maintained, the reference is valid. If a fuze order corresponding to 10 degrees of angular difference (1.4 fuze-seconds) between the pawls was applied to the previous projectile, the pawls must be displaced by 10 degrees after indexing the next projectile (provided the fuze-set order remains at 10 degrees or 1.4 seconds). Regardless of the value of the fuze order, the pawls are always initially one-half turn (180 degrees) behind the fuze-order signal.

The indexing and displacement of the pawls is accomplished as shown in figure 10-22. The pawl positions and angular differences selected are examples only. The operation is the same for any value of pawl angle or fuze order selected.

Both examples in figure 10-22 show the position of the holding pawl and setting pawls to give a fuze order corresponding to 10 degrees of angular difference or approximately 1.4 seconds of fuze time. After the fuze is set and the fuze setter is retracted, the setting pawl is displaced from its 10 degree position by one-half turn (180 degrees) counterclockwise.

The indexing signal in example A is disconnected from, and the synchro signal (fuze order) is connected to, the servo amplifier at the end of 2.3 turns of the pawls. This is a convenient point at which to switch, since both signals at this



EACH TIME THE FUZE SETTER RETRACTS, THE SETTING PAWL IS OFFSET 180° CCW TO DISPLACE THE PAWLS BEFORE THE NEXT INDEX CYCLE. THE COMBINED ROTATIONS OF THE SETTING PAWL AND THE HOLDING PAWL FOR ANY INDEX CYCLE TOTALS 900° (OR 2½ TURNS) TO ENSURE THAT BOTH PAWLS ENGAGE THEIR SLOTS IN THE FUZE.

53.337

Figure 10-22.—Index cycle functional diagram.

time saturate the force motor coils of the servo valve.

The synchro 1X control then brings the fuze setter to within four (4) degrees of the fuze order, after which the 5X synchro control brings the fuze setter to the desired setting. When indexing time is complete (2-1/2 turns), the fuze is set. Thus, the last 90 degrees of the indexing cycle (example B) is completed by the CTs and is actual fuze-set time. This is done to give more positive system control, to prevent hunting, and allow for tolerance in the indexing circuit.

For more detailed information on the Mk 29 fuze-setter, refer to OP 3713, volume 4.

Q24. How many turns must each pawl make before it aligns with its slot at maximum misalignment?

Q25. To within how many degrees will the synchro 1X bring the fuze to fuze time?

FUZE-SETTING EQUIPMENT FOR THE 5"/54 MK 45 GUN MOUNT

The Mk 30 Mod 0 fuze-setter (fig. 10-23), mounted on the loader drum at the transfer station, sets the mechanical time (MT) fuzes before the round is loaded into the upper hoist. Fuze orders from a remote source determine the time setting. Pressurized fluid (PA) from the lower accumulator system powers the hydraulic-mechanical components to extend and retract the fuze setter and to set the fuze. When the fuze is set and a firing order exists, the fuze setter retracts out of the way and the round is ejected into the upper hoistfor loading to the gun breech.

The main fuze-setter components consist of the fuze-setter assembly, fuze-setter actuating mechanism, and the fuze-setter amplifier.

FUZE-SETTER ASSEMBLY

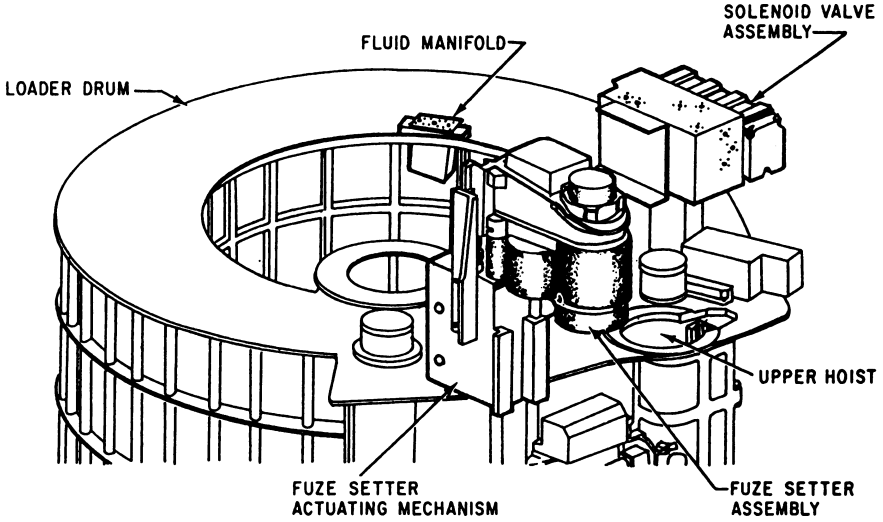
The fuze-setter assembly rotates the fuze-setter pawls to set a fuze. Components of the fuze-setter assembly are a housing, gearing, synchros (CTs), an electrohydraulic servo valve, a hydraulic motor, and a fuze pot.

Housing

The housing encloses the fuze pot, gearing, (CTs), and fuze-setting dial and provides a mounting surface for the hydraulic motor and electrohydraulic servo valve. A plexiglass viewing plate covers the fuze-setting dial. The dial, graduated in seconds, indicates fuze time.

Gearing

The fuze-setter gearing in the housing is a gear train consisting of spur gears and a differential.



53.338

Figure 10-23.—Location of fuze-setter and general arrangement. (Mk 30 Mod 0).

ANSWERS TO QUESTIONS Q21 THROUGH Q25.

A21. The servo valve.

A22. Friction between the pawls and the fuze.

A23. Two.

A24. One full turn.

A25. Four degrees.

The gearing, driven by a small hydraulic motor, drives the fuze-setting pawls. In addition, the gearing rotates the fuze-setting indication dial and drives the CT rotors.

Synchros

The two CTs inside the housing are connected to the gearing of the fuze-setter assembly. When fuze orders from the FCS or the EP2 panel are applied to these CTs, they produce electrical error signals, which are then applied to the fuze-setter amplifier.

Electrohydraulic Servo Valve

An electrohydraulic servo valve, in response to signals from the fuze-setter amplifier, controls the porting of hydraulic fluid to the hydraulic motor. Flexible hydraulic hoses connect the servo valve and the hydraulic motor to the fluid manifold.

Hydraulic Motor

The hydraulic motor, through the gearing, rotates the CTs and the setting and holding pawls. The fluid which operates the hydraulic motor is controlled by the servo valve.

Fuze Pot

The fuze pot, the circular extension at the base of the fuze-setter assembly, encloses two spring-loaded pawls. These pawls, a holding pawl and a setting pawl, engage slots in the projectile fuze. In response to fuze orders, the pawls rotate within a cone-shaped opening in the fuze pot, which fits over the fuze.

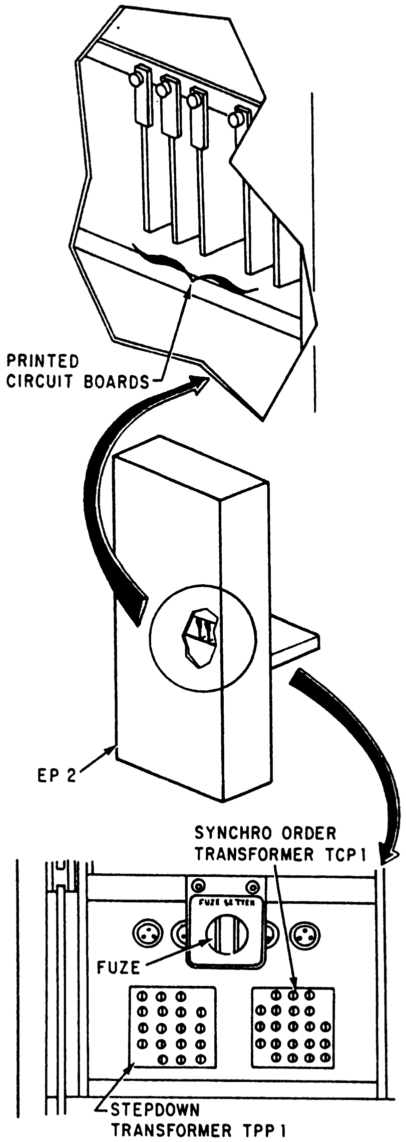
FUZE-SETTER ACTUATING MECHANISM

The fuze-setter actuating mechanism (fig. 10-23), located inside the loader drum opposite the transfer station, extends the fuze-setter assembly into engagement with the projectile fuze and retracts it out of engagement. Components of the actuating mechanism are a valve block, a latch, a slide, and slide guides.

A piston in the valve block vertically extends or retracts the slide within tracks of the slide guides. As the slide extends, the fuze-setter assembly engages the fuze on the projectile. When the fuze setter retracts (raises), a latch engages the slide to hold the fuze setter in the raised position. An interlock valve in the valve block operates the latch to latch or unlatch the slide.

FUZE-SETTER AMPLIFIER, MK 45 GUN SYSTEM

The fuze-setter amplifier (fig. 10-24) is located in the EP2 panel. It is a solid-state electronic amplifier that modifies the fuze orders used to operate the servo valve. The amplifier consists of a synchro order transformer (TCP1), a step-down transformer (TPP1), a fuze protecting the amplifier circuit, and three circuit boards which, except for the circuitry, are identical in appearance.



53.339

Figure 10-24.—Fuze-setter amplifier, Mk 45.

FUZE-SETTER INDEXING CYCLE

The fluid output from the servo valve operates the hydraulic motor. The hydraulic motor has a spline shaft extending into the fuze-setter assembly housing to drive the gear train.

During an indexing cycle, the pawls always rotate in opposite directions. In each indexing cycle, the setting pawl rotates counterclockwise or the holding pawl rotates clockwise, depending on internal gear friction, until both pawls drop into their respective fuze slots. After both pawls have locked with their fuze slots, only the setting pawl rotates to complete an index cycle. With a changing fuze order, the fuze setter synchronizes and follows an increasing or decreasing fuze order.

To rotate the pawls, the hydraulic motor rotates gear A through a series of spur gears (fig. 10-25). Gear A, along with flanged gear assembly B and splined disk C, fits over the spur gear shaft D. Since the splined disk at the top is secured to gear A, shaft D rotates along with gear E at the bottom of the shaft.

Flanged gear assembly B consists of a flanged internal gear fitting over an external spur gear. The flanged gear is secured to the fuze-setter assembly housing to prevent assembly B from rotating.

When gear E rotates in the differential gear, it drives gears F and G. Gears F and G are in a gear cage with gears H and J. Gears F and G drive the gear cage with gears H and J. Gears F and G mesh with internal spur gear K to drive the setting pawl, and gears H and J mesh with internal spur gear L to drive the holding pawl.

Internal friction of the unit determines which pawl turns first. When the setting pawl offers the least resistance, gears F and G drive gear K and the setting pawl rotates. If the setting pawl offers most resistance, gears F and G cannot drive gear K. With Gear E still driving F and G, however, that set of gears rotates (or walks) around gear K.

While gears F and G drive gear K to rotate the setting pawl, gears H and J do not rotate. In the opposite case, however, gears F and G walk around gear K and, because both sets of gears are enclosed in a gear cage, gears H and J rotate and walk around spur gear M. Since gear M is a component of flanged gear assembly B and is stationary, gears H and J drive gear L to rotate the holding pawl.

During an indexing and fuze-set cycle, the two pawls engage the slots on the projectile fuze through easement cuts on the fuze. After engaging the slots, the pawls continue to rotate to the desired fuze setting.

The Mk 30 Mod 0 fuze setter functions in the same manner as the Mk 29 does through the index cycle.

For more detailed information on the Mk 30 fuze setter, refer to OP 3392, volume 2, part 3.

Q26. Where is the Mk 30 fuze-setter located?

Q27. What controls the porting of fluid to the hydraulic motor?

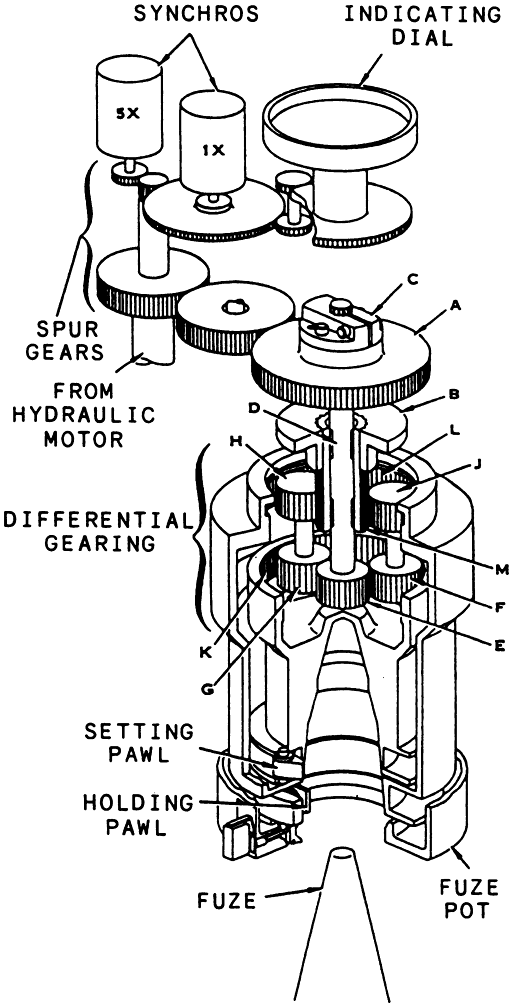


Figure 10-25.—Fuze-setter assembly mechanical diagram.

Q28. What action takes place when gear E (figure 10-25) rotates in the differential gear?

SAFETY

Safety precautions issued by Naval Sea Systems Command and such supplementary safety precautions promulgated in NAVSEA OPs related to ammunition and ammunition handling equipment must be observed. The following ordnance safety precautions are of a general nature. For special precautions for a specific type of ordnance equipment, reference should be made to that system's OP.

Modifications to ordnance handling equipment should not be made without approval of the Naval Sea Systems Command (NAVSEASYSCOM). Request or recommendations for modifications should be addressed to NAVSEASYSCOM and should include:

1. Complete details of the proposed modifications including photographs, drawings, and such engineering data as may be necessary.
2. Reasons for modifications and improvement expected to result from the proposed modification.

Whenever any item of equipment associated with an ordnance installation or weapons system has undergone overhaul or major repairs, the equipment should be tested to ensure satisfactory and safe operation prior to operational use. Such tests should include checks of proper operation and adjustment of safety devices.

Use safety devices provided for the gun system as designated. Keep the safety devices operative and in good order at all times. Inspect all safety devices frequently.

When safety devices are rendered temporarily inoperative, and, upon approval of competent authority, signs or other appropriate means should be used to warn personnel. Inoperative safety devices should be repaired (not secured). Alterations should be made to safety devices only after receiving direction from NAVSEASYSCOM.

Do not operate equipment without ensuring that all personnel are clear of moving equipment.

Post ordnance safety precautions in appropriate locations and place conspicuous warning signs at danger points. Use NAVSEASYSCOM safety precautions signs in accordance with current instructions.

No Gunner's Mate should be without total knowledge of the general ordnance safety precautions listed in *United States Navy Ordnance Safety Precautions*, OP 3347. The safety precautions listed in OP 3347 apply specifically to explosive and nonexplosive ordnance material and equipment located both ashore and afloat in facilities and units of the U. S. Navy.

In front of each new OP, there is a safety summary section that contains the safety precautions applicable to the particular gun mount and its associated equipment. Also, each OP contains a specific safety precautions section, which contains warnings and cautions.

SUMMARY

This chapter was devoted to increasing your understanding of the fuze-setting devices used on the 5"/38 and the 5"/54 Mk 42 and Mk 45.

We discussed the fuze-setting equipment that makes up the 5"/38 fuze-setting device, which consists of the fuze-setting indicator-regulator, fuze-setting chains, and the projectile flights. We also covered the subsystems of each component and how they work to set the fuze and keep the fuze time updated until it is loaded for firing.

In addition to the 5"/38, we discussed the 5"/54, Mk 42 Mods 9 and 10, and the Mk 45. The Mk 29 and the Mk 30 fuze-setting devices, as explained in this chapter, are very different in size, shape, and mounting position, but almost identical in operation.

To better understand the details of fuze-setting devices, you should refer to the applicable publication for the fuze-setter you are now (or will be) working with.

REFERENCES

Gunner's Mate G 1 & C, NAVEDTRA 10186-D1, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

ANSWERS TO QUESTIONS Q26 THROUGH Q28.

A26. On the loader drum at the transfer station.

A27. An electrohydraulic servo valve.

A28. It drives gears F and G.

CHAPTER 11

AMMUNITION HANDLING AND STOWAGE

This chapter on ammunition handling and stowage covers a large field. As a Gunner's Mate (Guns) First Class, you will be expected to perform each facet when the occasion requires you to do so.

The instructions pertaining to the handling and stowage of ammunition covered in this chapter are of a general nature. However, they should be strictly adhered to by all naval activities afloat and ashore. We could never cover all handling and stowage situations that could arise within this field. If every situation is not handled safely and intelligently, it could end with serious results.

Understanding all safety precautions and instructions listed in OP 3347, *Ordnance Safety Precautions;* OP 4, *Ammunition Afloat*; and OP 5, *Ammunition Ashore*, will better enable you to comprehend the principles upon which safety precautions and instructions are based. When you come upon a situation not covered by ordnance publications (during an emergency, for example), this knowledge may enable you to instinctively take the proper action.

As the leading Gunner's Mate, you will be required to prepare and implement ammunition loading and stowage plans. You will also be required to organize and administer a program of safety instructions and to supervise crews in procedures for transferring, handling, and stowing rockets, gun ammunition, mines, missiles, and any other ammunition that may be placed under your responsibility. Additional instructions for ammunition handling are found in various ordnance instructions and publications. Still others are furnished by Naval Sea Systems Command (NAVSEASYSCOM).

According to OP 4, the term "ammunition" includes all components and any and all explosives in any case or contrivance that is prepared to form a charge, complete round, or cartridge for small arms, rifle, gun, cannon, or for any other weapon, or for explosive-actuated devices, impulse device, torpedo warhead, mine, bomb, depth charge, demolition charge, fuze, detonator, projectile, rocket, or guided missile. Ammunition includes all solid propellants as well as all hypergolic liquid propellant systems and other hazardous materials applied to ordnance uses and/or requiring surveillance for reasons of explosive safety. It also includes all JATO units, boosters, sustainers, military pyrotechnics, and offensive chemical warfare materials.

All ordnance safety precautions are explicit and allow no leeway. Whenever ammunition or explosives are being received, transferred, stowed, or prepared, the paramount consideration should always be safety and reliability. Because of its sensitivity, no work with ammunition and explosives should ever be a part of a competitive evolution.

Q1. To understand the principles on which ammunition handling safety precautions are based, what three publications should you study?

Q2. What are the two paramount considerations when working with any type of ordnance?

ALLOWANCE LISTS

The Naval Sea Systems Command ensures the promulgation of the allowances of ammunition established by the Chief of Naval Operations (CNO). This is done by using NAVSEA ammunition allowance lists (30000 series) and NAVSEA instructions, which establish the full allowances. The source of supply for the NAVSEA ammunition allowance lists is the Navy Ship's Parts Control Center (SPCC Code 730), Mechanicsburg, Pennsylvania.

Generally speaking, there are two ammunition allowances for each ship. One is the shipfill allowance that is required for combat readiness; the other is the training allowance, or that portion of the full load which is expended yearly in training. Remember that CNO establishes a ship's full load allowance (including target ammunition) when the ship is initially outfitted.

SHIPFILL AMMUNITION ALLOWANCES

A NAVSEA ammunition allowance list (30000 series) is issued to each vessel in active service—listing the full war allowance of ammunition which is authorized that particular ship. Another NAVSEA ammunition allowance list, also in the 30000 series, is issued to certain ships such as aircraft carriers, ammunition ships, and others listing prescribed types and amounts of ammunition that ship is required to carry as a mission load/cargo load. This allowance is to be carried in addition to the regular service allowance.

Cognizant fleet, force, and type commanders may authorize temporary deviations from these allowances whenever it is necessary to meet scheduled or anticipated operations. However, requests for major revisions of NAVSEA ammunition allowance lists should be directed to the CNO, through the appropriate chain of command and NAVSEASYSCOM Headquarters. Requests for minor changes or substitutions of types should be forwarded directly to NAVSEASYSCOM.

Each shipfill allowance list prepared for new construction or revised for major conversion/regular overhaul will be issued as an interim list. This is limited to shipfill lists and requires fleet validation. When each list is validated by the fleet, or within 6 months' maximum time, it is replaced with a finalized allowance list bearing a new revision letter and date.

TRAINING AMMUNITION ALLOWANCES

The training ammunition allowances for all phases of active fleet training as established by the CNO are promulgated in NAVSEAINST 8011. These instructions set forth the various training allowances for each year and remain in effect until modified or canceled. Allowances as prescribed are for the purposes and periods as specified only. Any unexpended allowance at the termination of a specific cruise or fiscal year as appropriate, is automatically canceled.

Should an augmentation of the allowance of specific type, or types, of training ammunition be desired, a request may be made to the cognizant fleet or type commander. Requests for special allowances in excess of regular training allowances, and requests for permanent modifications of training allowances should be addressed to the CNO through the appropriate chain of command and NAVSEASYSCOM.

Ammunition allowances, both service and training, constitute the necessary authority for requesting ammunition from ammunition facilities. Care must be taken to ensure that all requested ammunitions conform with the space, weight, stability, and immersion limits prescribed by NAVSEASYSCOM and the limiting weight of ammunition as specified in the ship's ordnance equipment list. Also, the cumulative total of training ammunition requested must not exceed the annual allowance.

Further information on requesting ammunition will be given in chapter 12, "Administrative Duties."

Q3. How many types of ammunition allowance lists are prepared?

Q4. Requests for major revisions to ammunition allowance lists shall be made to what two offices?

ANSWERS TO QUESTIONS Q1 AND Q2.

A1. OP 3347, OP 4, and OP 5.

A2. Safety and reliability.

Q5. To whom should a request be made for an augment of training ammunition?

GENERAL REGULATIONS FOR HANDLING AMMUNITION

Questions regarding the policies governing the issuance of ammunition, or discrepancies noted when receiving ammunition from another activity, should be referred to the issuing activity or NAVSEASYSCOM. NAVSEASYSCOM will settle questions on the proper disposal of obsolete or unserviceable ammunition, and shall be informed of those cases where partial orders of incompatible substitutions were made.

OP 4 states that instructions for the handling of ammunition and explosives in port areas within the confines of naval districts are established and promulgated by the Chief of Naval Operations.

During peacetime, the hazards involved in handling large quantities of ammunition are considered too great at places other than those specifically designed for these operations. There are two types of locations where loading and offloading of large amounts of ammunition are authorized.

1. Certain ammunition activities with appropriate piers have been designated by NAVSEASYSCOM as ordnance facilities. These activities have been cleared for the issuance, loading, unloading, and receipt of ammunition to these piers and are available for these functions.
2. Certain berths or areas, indicated on applicable harbor charts as explosives anchorages, have been designated by the Army Corps of Engineers, Department of the Army, as authorized for use by vessels for the loading and offloading of ammunition.

To conform with local safety requirements and restrictions, the general instructions issued by the CNO may be further amplified or detailed by the cognizant naval districts, by ordnance facilities, and by other proper authority.

EXCEPTIONS

Where the characteristics of a vessel preclude the use of an ordnance facility or an explosives berth, naval districts may designate other locations where loading or unloading of ammunition can be accomplished. This exception applies only to the following types of ammunition and where specified, within the limits of size or quantity: small arms; rockets (5-inch and smaller); gun and mortar; grenades; chemical (except lethal toxic); fuzes, primers, detonators; pyrotechnics; impulse, blank, saluting charges; JATO units for aircraft takeoff; and JATO igniters (not to exceed 20 of each).

Certain facilities may be designated by the CNO where small quantities of ammunition may be transferred to and from ships under conditions prescribed by naval districts. This exception applies generally to the transfer of ammunition required for tests, training, saluting, and other minor replenishment of other types of ammunition. When operations at piers under the two exceptions above are authorized, ammunition must not be offloaded from a ship until transportation is available to remove it promptly, nor will it be transported to the pier for loading until the ship is ready to receive it.

Q6. Who designates certain berths or areas as explosive anchorages?

Q7. Where characteristics of a vessel preclude the use of a designated facility, who may designate an alternate location for loading?

RESPONSIBILITY FOR PROPER HANDLING

The general areas of authority and responsibility in the case of a ship berthed within the jurisdiction of an ordnance facility are set forth by OPNAVINST 8023.2. No attempt will be made in this book to cover all existing safety precautions. However, some of those pertaining to safety in connection with the transfer of ammunition are as follows.

The commanding officer of the vessel has direct responsibility for compliance with all safety regulations within the ship while it is at a pier, a dock, or in adjacent waters as defined by local regulations. Ammunition or explosives are considered "within the ship" when their weight is carried in whole or in part by the ship.

No emergency drill requiring the use of the general alarm, ship's bell, whistle, or siren should be held on board ship during ammunition or explosives handling operations while alongside an ammunition or explosives pier, as such action might lead to a misunderstanding.

In the event of an emergency, and upon the appropriate signal from qualified personnel, all operations involving ammunition or explosives must stop immediately.

All firemains on board a ship actually engaged in loading or discharging operations should be inspected to ensure efficient functioning. Those firehoses to be used in the event of a mishap should be prepared and ready for use. The last thing you need is to have a situation requiring the use of a firehose and have it not function as designed (the sudden gush of water and a trickle till it stops works fine on the number three drain line of a sprinkler system, but not on a firehose). The firehose valves controlling the hoses should be cracked open (except in freezing weather) so that casual observation may indicate that water is available.

GENERAL INSTRUCTIONS

In addition to the general instructions in this book, the applicable safety precautions of OP 3347 should be thoroughly understood by all personnel concerned with the handling of ammunition and explosives.

To ensure its proper functioning, ammunition should be prepared, overhauled, assembled, stowed, and shipped according to exact requirements. Improper, rough, and careless handling of ammunition, ammunition components, and ammunition details may result not only in its malfunctioning; but of greater importance, it may cause accidents which result in damage or loss of life. The history of accidents which have occurred in the use, handling, shipping, and stowage of ammunition shows that, in practically every instance where the cause could be determined, the accidents have been due to circumstances that were avoidable. Many of these examples and case histories are contained in OP 1014, *Ordnance Safety Precautions, Their Origin and Necessity.*

Repetitious work, no matter how dangerous, is likely to become routine and lead to carelessness. Therefore, constant vigilance and intelligent close supervision must be maintained to prevent accidents in operations involving ammunition and explosives.

Utmost care must be exercised when handling all kinds of explosives, ammunition, ammunition components, and ammunition details. This pertains to all personnel connected with naval service.

Handling of ammunition should never take place during refueling operations or when loading flammable stores. Except in emergencies, ammunition shall not be transferred during fueling operations ashore. This paragraph does not restrict the simultaneous transfer of fuel and ammunition during underway replenishment at sea.

Q8. General areas of authority and responsibility in the case of a ship berthed within the jurisdiction of an ordnance facility are set forth in what instruction?

Q9. When does a commanding officer assume responsibility for ammunition being loaded onto his vessel?

ANSWERS TO QUESTIONS Q3 THROUGH Q7.

A3. Two.

A4. CNO and NAVSEASYSCOM.

A5. Cognizant fleet or type commander.

A6. Army Corps of Engineers.

A7. Cognizant naval district commanders.

Q10. Except in freezing weather, why is a firehose left cracked open during ammunition handling evolutions?

Q11. What publication gives examples and case histories of ordnance accidents?

Q12. Handling of ammunition must never take place during what two evolutions?

SUPERVISION OF PERSONNEL AND EQUIPMENT

When ammunition or explosives are being received, transferred, or stored, the work should be supervised by an officer or petty officer who is thoroughly familiar with the rules for the care and handling of explosives. It is the responsibility of the supervisor to ensure that all persons engaged in the work are properly impressed with the necessity for exercising the greatest care.

Personnel Requirements

Personnel engaged in ammunition and explosives operations should be limited to the number necessary for the safe and efficient performance of the work at hand. However, a sufficient number should be employed to ensure safe handling and to ensure a steady flow of ammunition without undue concentration at any point.

Personnel assigned to ammunition and explosives operations should be adequately trained in this type of work. All operators of mechanical handling equipment such as cranes, winches, and booms must be specifically qualified to operate the equipment to which they are assigned.

Equipment Requirements

The following paragraphs apply to equipment used for moving explosives and ammunition. You should refer to OP 2173, *Handling Equipment for Ammunition and Explosives*, for a detailed study of the handling equipment you will or may encounter.

TYPES AND AMOUNT OF EQUIPMENT.—OP 4 states that handling operations must never be started until adequate equipment is available. Any ammunition activity will provide the required portable equipment upon request. Plan ahead—this request is best accomplished by message or phone call upon arrival.

Approved special handling equipment for special type of ammunition, such as projectile carriers and bomb trailers, should be used whenever the equipment is available.

Slings used for handling ammunition and explosives should be of all-rope or of all-wire construction, never a combination of the two.

CONDITION OF EQUIPMENT.—All equipment regardless of size, shape, and use should be properly maintained and frequently inspected throughout its use to ensure that it is in proper working condition and of adequate capacity to safely serve the purpose for which it is intended. Condition of equipment inspections should be made prior to, and frequently during, loading and unloading operations.

All electrical equipment, such as winches and motors, should be inspected by a qualified electrician prior to use and frequently during operation.

Brakes and controllers of hoisting motors should be in efficient operating condition, and hoisting speeds should be regulated to lessen the danger of jams or parting lines.

Shipboard slings, crane cables, and boom cables should be tested periodically for operating strength in accordance with NAVSEASYSCOM requirements.

Protruding nails or similar sharp objects, loose powder, other combustible materials, or unauthorized flame-producing devices are strictly prohibited on transportation equipment.

Responsibility for the operating condition of handling and transportation equipment rests with the ship and ordnance facility for their material.

Equipment that shows signs of weakness or undue wear should be rejected. Chapter 1 of OP 3347 prescribes the requirements for inspection and testing shipboard ordnance handling equipment. Armament handling equipment used for aircraft loading/down loading of explosives should be tested in accordance with NAVAIR 19-600 series MRCs.

USE OF HANDLING EQUIPMENT TO LIMIT DAMAGE.—Handling equipment should never be loaded to the limit of its maximum rated capacity.

All gangplanks, gangboards, ramps, bridge plates, skids, and similar equipment should be of such strength to carry the imposed load.

Explosives or hazardous materials, whether in containers, in bulk, or loaded into projectiles, cartridges, or ammunition components, must be handled carefully to prevent shock or friction that may cause fire, explosion, or damage. These materials must not be thrown, dropped, tumbled, dragged, or pushed over the deck or over other containers.

During the handling of ammunition, every precaution should be taken to avoid contact with sand, earth, gravel, or other abrasive or spark-producing substances.

Ammunition and explosives containers should be hoisted and lowered steadily and slowly, using mattresses to prevent damage. Such cushions are not required when handling palletized material. Ample time should be allowed for proper removal of a hoist after the landing.

Q13. For a detailed study of explosives and ammunition handling equipment, to what publication should you refer?

Q14. What publication lists the inspection and testing requirements for handling equipment?

LOADING/OFFLOADING PLAN

Prior to loading or offloading any ammunition (other than the small amounts which will be handled by qualified weapons personnel), a workable ammunition handling plan should be outlined and promulgated in the form of a weapons department notice. The ship's organization manual may include a standard loading plan. If not, you can most assuredly find a precedent in your weapons department files of instructions and notices. This plan can be used as a guideline, but will very likely have to be altered to meet present circumstances.

Your loading plan should include the following information:

1. A sketch or drawing showing the positions of all stations where ammunition will be taken aboard; and, if the ship is to be at an anchorage, the positions that all barges, camels, cranes, and associated equipment will take alongside the ship.
2. The types and amounts of ammunition to be taken aboard at each station.
3. A clear description of the route that each type of ammunition will take from the onload station to the magazine.
4. A list of personnel assigned to each station, providing for rotation, chow relief, and change of station upon completion of comparatively short assignments.
5. A list of the ammunition handling equipment to be supplied at each station by the ship. This equipment should be thoroughly inspected before the operation.
6. A list of the ammunition handling equipment to be supplied by the ammunition or other facility, and where the equipment will be required. This will include such equipment as cranes, conveyor belts, bomb trucks, and electric forklifts.
7. Smoking areas (if any) should be defined.
8. All pertinent safety precautions must be listed.

ANSWERS TO QUESTIONS Q8 THROUGH Q12.

A8. OPNAVINST 8023.2.

A9. When the weight of the ammunition or explosives are carried in whole or in part by the ship.

A10. So that casual observation may indicate that water is available.

A11. OP 1014.

A12. During refueling operations or when loading flammable stores.

9. A list of the types and amounts of ammunition to be loaded into each separate magazine. (A loading plan for each magazine should be given to the officer or petty officer in charge of its stowing.)

Depending on the circumstances, you may well find other important items to add to your loading plan. An offloading plan includes much of the same information as the loading plan, except, of course, that routings and participants might be different.

Ensure that all persons in a supervisory capacity receive a copy of this plan. If at all possible, supervising petty officers should be assigned to stations where personnel of their own division are working. This will prove especially helpful should it become necessary to shift large groups to another station during the operation.

Q15. Step 4 of the loading plan should include what information?

INSPECTION BEFORE ACCEPTING

Prior to acceptance of a shipment of ammunition and explosives, a ship's representative, in company with an ordnance facility representative (the supervisor in case of a loaded lighter), should inspect the seals of the vehicle and check the general condition of the shipment. It is imperative that the following checks be accomplished:

1. See that the material is properly boxed in correct shipping containers. See that there are no leaky containers, and that none are broken or so weak as to break during transportation. In those cases where leaky containers or other damaged materials are being turned into an ammunition activity (offloaded), see they are plainly marked and segregated from other materials.
2. See that the total quantity shipped and/or received is in agreement with the invoice (if feasible at this point).
3. See that the material is properly stowed or stacked and braced in the vehicle to prevent damage to containers or contents and in accordance with applicable regulations.

A red flag should be prominently displayed during daylight and a red light at night by any vessel or barge transporting, onloading, and offloading explosives or ammunition.

OPERATION AT NIGHT

Live ammunition and explosives should not be loaded on or discharged from a ship or lighter at night except in an emergency or when required by the vessel's sailing schedule, or as authorized by NAVSEASYSCOM. Piers should be adequately lighted and equipped with fire protection and safety equipment. If loading or unloading is not completed during the day, proper precautions should be taken to guard and protect against fire, and a sufficient crew should be on hand to adequately cope with emergencies that might arise. If night operations are required, only carefully placed, approved electric lights, portable lanterns, or flashlights should be used inside the ship or lighter, or in the adjacent areas.

Lighting equipment should meet the standards of the National Electric Code as follows:

1. Extension lights should be fitted with exterior globes and stout guards to protect the bulbs.
2. Wire leading to the lights should be sound and heavily insulated to show no evidence of being likely to short circuit.
3. Extension lights should be suspended in such a manner that no strain is carried by the light cable; they are not to be suspended by the cable.
4. Extension lights should be so guarded and protected that neither the light nor the light cable will be in contact with any metal part of the ship, lighter, vehicle, handling equipment, or with any of the ammunition, explosives, or their containers.
5. Extension lights should have an outside power source not connected in any way to the lighter, railroad car, truck, or vehicle.

METHODS OF HANDLING

Handling ammunition should be kept to a minimum to prevent damage and to reduce chances of accidents.

Precautions to be Observed

The precautions for moving projectiles, powder, cartridge containers, and tanks are covered in chapter 3, OP 3347, *United States Navy Ordnance Safety Precautions*, and will not be reproduced here. You should refer to chapter 3 of OP 3347 and become familiar with its contents.

Special Precautions for Bomb-Type Ammunition

Bomb-type ammunition includes aircraft bombs, mines, warheads, depth charges, and certain types of rocket heads and projector charges, which are characterized by a large high explosive charge-to-weight ratio. This type ammunition is particularly susceptible to container-dent-sensitivity because its thin walls are relatively easy to rupture or dent. Denting the thin walls of a container by impact has caused partial or complete detonation. A certain degree of confinement, combined with a local heating of the contained explosive by a particular kind of impact, have been known to cause instantaneous explosive action.

Prior to transfer, the issuing activity should indicate all existing damage, no matter how slight, by circling it with white paint. This will identify any new damage to the container and allow the receiving activity the opportunity to inspect the material prior to receipt. The receiving activity should report in full detail, with documentation and photographs where possible, all instances where bomb-type ammunition was received with uncircled dents. This report should be sent to NAVSEASYSCOM and a copy forwarded to the activity from which the ammunition container was received.

Hazards of Electromagnetic Radiation to Ordnance (HERO)

The technical manual, *Radio Frequency Hazards to Ordnance, Personnel and Fuel*, OP 3565, should be used by all commands as a guide in handling and stowing ordnance items containing electroexplosive devices which may be affected by electromagnetic radiation. The manual outlines detailed requirements, procedures, and restrictions prescribed for handling many ordnance items and general restrictions applicable to all ordnance items containing electroexplosive devices. Because of the nature and constant changing requirements of ordnance devices, HERO will not be covered here. OP 3565 is required reading and a PQS standard; therefore, it should be studied to thoroughly understand its contents.

To ensure the HERO safety and HERO reliability of ordnance systems, NAVSEASYSCOM sponsors an extensive testing program to determine their susceptibility to rf (radio frequency) energy. These tests are conducted in the maximum rf environmental levels to which the ordnance may be exposed under actual handling and loading conditions.

AMMUNITION STOWAGE ABOARD SHIP

Detailed specifications for construction of U.S. Navy ships, and individual ship's blueprints developed and approved by NAVSEASYSCOM establish and designate ammunition stowage spaces for various ship types, classes, and modifications. Where aircraft carriers or aircraft are involved, ammunition stowage spaces should also satisfy NAVAIRSYSCOM requirements. Various categories of explosives and ammunition normally are stowed in separate magazines or lockers so that the highest degree of safety is obtained. All magazines should be marked by appropriate label plates designating the compartment and the types of ammunition to be stowed therein; i.e., powder magazine and detonator lockers. Primary and missile magazines are designed to hold a ship's peacetime and training allowance. Ready-service magazines may be used to stow additional ammunition to fill a ship's wartime allowance. Any deviation from the normal should be referred to NAVSEAYSYSCOM. Unsatisfactory stowage conditions and magazines that do not comply with NAVSEA OP 3347 and other applicable instructions, should be reported to NAVSEASYSCOM

ANSWERS TO QUESTIONS Q13 THROUGH Q15.

A13. OP 2173.

A14. Chapter 1 of OP 3347.

A15. Personnel assignments.

with a request for instructions on how to correct the deficiencies.

TYPES OF MAGAZINES

Many different types of magazines are provided on ships. Each magazine is designed specifically for the type of ammunition it will contain. The magazine types include primary, missile, ready-service, lockers, and chemical.

Primary Magazines

Primary magazines are stowage spaces that usually are located below deck and if possible, below the waterline. They are adequately equipped with thermal insulation, ventilation, and sprinkling systems—and they shall be closed and locked.

Missile Magazines

Because of the nature of guided missiles, requirements for their stowage aboard ship differ from conventional ammunition magazine requirements. Surface-launched missiles are normally stowed above the waterline, while air-launched missile magazines usually are located below the waterline within the armor box. Air-launched missile ready-service magazines may be located above the waterline or in the armored box. Various missile magazines are equipped with special monitoring equipment. Special care should be taken with the vent system of missile magazines to ensure that magazine pressures do not build up to a dangerous level if a missile motor is ignited. A plenum vent and/or a relief port is provided for this purpose. Additional firefighting equipment may be installed depending on the type of missile stowed.

Ready-Service Magazines

Ready-service stowage denotes the ammunition stowage facilities in the immediate vicinity of the weapon or space to be served, such as weather deck lockers, bulwark racks, and upper handling rooms. This stowage is used only when the ammunition is actually required to service the weapon. Even then, the amount stowed should be kept to a minimum except for weapons stowed in the all-up condition. All ready-service magazines should be kept locked when not in use.

Lockers

Certain compartments or lockers are provided for the stowage of special types of ammunition and ammunition components, such as detonators, pyrotechnics, and chemicals. They are frequently installed on weather decks and are of the jettisonable type.

Chemical Magazines

Chemical ammunition, classified as lethal or incapacitating, should not be carried aboard ship unless specifically authorized by the CNO, who will provide detailed instructions and personnel trained in handling this type of ammunition.

DESIGNATION OF MAGAZINES

Magazines or ammunition spaces afloat are designated with particular reference to the purpose intended. Insofar as is practicable, magazines are designated to hold a single type of ammunition.

Single-Purpose Magazine

The following designations are given for magazines whenever a single-purpose stowage is practical: powder and rocket motor magazines; fixed ammunition magazines; small arms magazines; missile magazines; warhead lockers or magazines; aircraft bomb magazines; projectile and rocket head magazines; fuze magazines; detonator lockers; pyrotechnic magazines or lockers; ready-service ammunition rooms, boxes, racks, or lockers; and chemical magazines. While stowage of a single type of ammunition in individual magazines is desirable, it is not always possible. NAVSEASYSCOM has authorized certain mixed stowages in magazines that retain single-purpose designations.

Multipurpose Magazines

Where stowage space is limited and the mission requires carrying various types of ammunition, stowage of more than one type of ammunition in a single magazine is an acceptable hazard. Authorization for this type of stowage is at the discretion of the operational commander. When in doubt about stowage requirements and compatibility, it is always best to refer to your governing documents and publications. OP 4, *Ammunition Afloat*, dedicates chapter 3 to this subject and should be studied to clear up any doubt you may have in this regard.

Q16. What manual outlines detailed requirements for handling ammunition containing electroexplosive devices?

Q17. Where are surface-launched missiles normally stowed?

Q18. When in doubt about stowage requirements and compatibility, it is always best to refer to what publication?

MAGAZINES FITTINGS AND EQUIPMENT

Magazines, according to their type, are fitted with environmental control and safety features to protect ammunition from excessive temperatures and humidity. Refer to OP 4, *Ammunition Afloat*, chapter 3, for material covering hypergolic engines and fuel-air-explosives (FAE) and the stowage requirements of these explosives.

Most magazines are equipped with some form of mechanical cooling or ventilation system. As you will find, some ships in the fleet have magazines that do not have either of these systems. You must therefore monitor these magazines more closely. Table 2-2—Temperature Control Guidelines—of OP 4 contains an excellent listing of pyrotechnic materials that are affected by various stages of heat. To understand the effects of heat on various materials, refer to this table. If a magazine has a heat gain of over 100 °F without controls, the space must be ventilated or mechanically cooled, depending on the available facilities. There have been occasions where a pyrotechnic locker or ready service magazine has been cooled with a garden hose on a hourly basis. Whatever it takes to do the job is usually the route one must take.

Aside from the cooling systems installed in our magazines, we need periodic blowout air for magazines that are manned during general quarters. Blowout air, which is required infrequently and for very short periods, may be acquired by opening the supply vent and exhaust closures—located either in the same compartment or in an adjoining compartment. If the supply/exhaust system is located in an adjoining space, you will need to open a passing scuttle in the hatch or a watertight door between those spaces during ventilation.

Magazines are fitted with temperature boards, brackets for tank wrenches, hooks for thermometers and buckets, shelves, eyebolts, and pad eyes as required by the ammunition they contain. The lowest rows of ammunition should be positioned high enough off the deck to allow cleaning under them. Portable metal platforms should be stowed in magazines where ammunition is stowed too high for convenient handling from the deck. Portable fittings are permitted in aisles and passageways if handling space is adequate. Piping should not be routed through magazines unless it is required for the magazine, or unless no other routing is possible. This restriction also applies to electric cabling.

SPRINKLING SYSTEMS

Primary and missile magazines, ammunition handling rooms, and most ready-service magazines are required to be fitted with sprinkler systems. Sprinkler systems should consist of spray heads or sprinkler head valves arranged to impinge water directly on munitions and provide complete coverage. Weather deck lockers do not require sprinkling systems. If there is no designated black powder magazine aboard, ready service rooms or lockers equipped with sprinkler systems may be used.

Since magazine sprinkler systems are covered in depth in the *GMM 3 & 2* and the *GMG 3 & 2* TRAMANs, the use of sprinklers will not be covered within this text. Additional reading on sprinkler systems and firefighting equipment is available in NAVSHIPSTECHMAN, chapter 555, volumes 1 and 2.

IDENTIFICATION OF AMMUNITION STOWAGE SPACES (FAR SIDE)

Shipboard ammunition stowage spaces should be marked to provide rapid and positive identification. This marking enables any individual to be aware of the presence of ammunition stowage and act accordingly in the event of fire or other danger. *Naval Ship's Technical Manual*, chapter 700, and OP 4, volume 2, contain a complete description of how and where these marking labels are to be installed.

AMMUNITION PASSING SCUTTLES

Ammunition passing scuttles are of two types—rotation and flap. These scuttles are provided to prevent flames from passing along the route of the ammunition supply. The rotation type gives a seal only while the flap is closed. For care and inspection of the above scuttles, refer to *Naval Ship's Technical Manual,* chapter 700, and OP 4, volume 2.

WORK LIMITATIONS AND SECURITY OF MAGAZINES

Before performing work that may cause abnormally high temperatures or intense local heat in magazines, magazine areas, or adjacent spaces, all explosives and ammunition should be moved to a safe stowage. This refers to work that requires cutting or welding torches and similar work in or near the magazine, as well as the steaming out of oil tanks and compartments.

Fuzing and unfuzing of bomb-type and rocket ammunition should not be done in or near magazines. Detonators, boosters, primary detonators, or other fuzing mechanisms should not be assembled in bomb-type ammunition in or near magazines.

In peacetime, all magazines, explosive lockers, ready- service boxes, and magazine ammunition hoists should be kept closed and locked except when they are open for inspection, ventilation, testing, or authorized work. They should be opened only when authorized by the officer in charge of the space, who shall be responsible for securing the locks upon completion of the operation. Magazine keys should be kept by the commanding officer or any officer designated as the custodian.

In time of war, and at the discretion of the commanding officer, magazines, explosive lockers, and ready-service lockers need not be secured with locks, but should be fully dogged closed. Watch this dogging of magazine doors and hatches because personnel taking daily magazine temperatures may have a tendency to secure the doors and hatches with just a few loose dogs to permit easy access to the magazine during the next round of taking temperatures.

READY-SERVICE STOWAGE

Ammunition should not be stowed in ready-service stowage unless needed at the weapon, and then the amount so stowed should be kept to a minimum. Such ammunition is subject to rapid deterioration and must be specially examined before being returned to a magazine. If such ammunition is returned to a magazine, it must be segregated and fired first at the next authorized firing.

Ammunition in ready-service stowage should be protected with suitable covering from the direct rays of the sun and from weather. Maximum and minimum thermometers should be placed in all ready-service boxes that contain ammunition, and the temperature should be recorded daily. Should the temperature of these boxes exceed 100 °F, the following steps must be taken to effect artificial cooling:

1. Protect boxes from direct rays of the sun with awnings and screens.
2. Cover boxes with wet blankets or similar materials.
3. Maintain good circulation of air around the boxes to produce evaporation in the wet blankets.

Should any ammunition containing smokeless powder be exposed to temperatures in excess of 110 °F, a log of the temperatures and number of hours so exposed should be maintained. The procedure that should be followed if the ammunition remains in ready-service stowage exposed to temperatures in excess of 110 °F for a cumulative total of 500 hours is described in *Ammunition Afloat,* OP 4. Should ammunition containing smokeless powder be exposed to temperatures in excess of 110 °F for any period of time and then returned to the magazine, it must be segregated and issued first for firing and for further ready-service stowage. Any further exposure to temperatures in excess of 110 °F will be added to the cumulative total and, when 500 hours of such exposure has occurred, the procedure described in OP 4 must be followed.

Q19. In addition to the 3 & 2 rating TRAMANs, additional reading on sprinkler systems may be found in what publication?

REGULATIONS FOR STOWAGE OF AMMUNITION

The stowage regulations prescribed here (from OP 4) must be followed unless compelling reasons dictate otherwise. In such situations, the chart of permissible stowages (OP 4) must be used in determining the types of ammunition that may be stowed together.

SMOKELESS POWDER

Smokeless powder charges are stowed in magazines separate from other types of ammunition. Preferably, each type and size of smokeless powder charge should be stowed in a separate magazine. The magazine should be provided with insulation, ventilation, and a sprinkling system. However, on some smaller ships, insulation may not be available. Ships whose magazines are not exposed to abnormal temperatures may not be provided with ventilation systems. Except in the case of small arms and fixed ammunition, smokeless powder charges in cartridges should not be stowed in the same magazine with projectiles. Tanks for major caliber bag charges are stowed so that all covers are removable without disturbing the other tanks.

Separated cartridges should be stowed in separate magazines. If practicable, separated ammunition of different calibers should be stowed separately. When space limitations exist, rocket motors may be stowed with separated cartridges. Fixed ammunition must be stowed in separate magazines. Due to the constant change in ammunition and other explosives, it is always best to consult the latest publications available to ensure compatible stowage.

The most important factor in the stowage of smokeless powder is magazine temperature. The most important causes of the rapid decomposition of smokeless powder are high temperatures, excessive moisture, and the presence of acid. Experience has indicated that stowage in airtight containers at or about 70°F or less is entirely satisfactory for the normal life of any service powder. However, the stability of the powder diminishes rapidly as stowage temperatures rise, and it is seriously threatened at above 100°F. Therefore, every effort should be made to maintain magazine temperatures below 100°F.

For information covering abnormal exposures of ordnance to temperatures, refer to OP 4. When confronted with ordnance exceeding limitations where disposal at sea is necessitated, refer to NAVSEAINST 4570.1 for safe dumping overboard.

If you are striving to become a GMG1, you will be subjected to examination questions on the types and characteristics of demolition explosives and safety precautions for their handling and stowage. *Gunner's Mate G 3 & 2*, NAVEDTRA 10185, covers the types and characteristics of demolition explosives.

DETONATORS, FUZES, AND BOOSTERS

Detonators for bomb-type ammunition, and other detonators requiring stowage separate from ammunition in which they are to be assembled, should be stowed separately in detonator lockers. Such lockers should be located in approved places below the waterline or protective deck in large ships, and above the weather deck in small craft. The locations are approved by NAVSEASYSCOM and are shown on the ship's plans. No more than 100 detonators should be stowed in any one locker and no two lockers should be less than 10 feet apart. Individual detonators should be stowed in standard containers or in specially designated stowage blocks.

Detonators should never be stowed in proximity to high explosive charges, or adjacent to bomb-type magazines. They **MUST** be kept away from fires, steam pipes, electric apparatus, and locations which are liable to heavy shocks. Electric detonators should not be located in the same compartment with, or within 5 feet of radio apparatus or antenna leads. Separately packaged detonators should not be stowed in a fuze magazine that contains explosive-loaded fuzes,

ANSWERS TO QUESTIONS Q16 THROUGH Q19.

A16. OP 3565.

A17. Above the waterline.

A18. Chapter 3 of OP 4.

A19. NAVSHIPTECHMAN, chapter 555, volumes 1 and 2.

explosive boosters, or explosives of any kind other than detonators.

Fuzes and boosters, which are not permitted to be stowed assembled in bomb-type or other ammunition, should be stowed in specially designated fuze magazines, which should not be located adjacent to magazines containing high explosives. Ready-service fuze stowages are located at assembly points or near launchers and are shown on ship's plans. Mechanical time fuzes and point detonating fuzes for interchangeable assembly in separate loading projectiles may be stowed in specially designated lockers located within the projectile magazine, or close to projectile hoists within the gun installation. Electrical or proximity (VT) fuzes should never be stowed in the same compartment with, or within 5 feet of, radio apparatus or antenna leads.

GRENADES

Hand grenades loaded with explosive composition (E.C.) powder only, and fuzed, may be stowed in small arms magazines. Fragmentation hand grenades that are high explosive loaded, plugged, and have the fuzes removed, may be stowed in separate loading projectiles or fixed ammunition magazines. Offensive rifle and hand grenades that are high explosive loaded, but without fuzes, may be stowed in bomb-type magazines. On ships where there are no bomb-type magazines, these grenades may be stowed in a grenade body locker. White phosphorus (WP) smoke, rifle and hand grenades, which are plugged and have the fuzes removed, may be stowed like chemical ammunition, separate from other types. Rifle and hand grenades, tear gas (CN), plugged and with fuzes removed, may be stowed in chemical ammunition magazines. Dummy rifle or hand grenades (dummy drill ammunition) should not be stowed in a magazine.

IGNITERS

Torpedo igniters and JATO igniters may be stowed in a fuze locker or fuze magazine. The igniters should not be stowed in the same compartment with, or within 5 feet of, radio apparatus or antennas leads.

Detonators which are not assembled and sealed within a fuze as an integral part of it (i.e., detonators requiring separate stowage) should not be stowed in a fuze magazine that contains explosive-loaded fuzes, explosive boosters, or explosives of any kind other than detonators.

Except when required for ready-service stowage or when assembled in ready-service ammunition, fuzes, and boosters should be kept stowed in their individual containers, usually hermetically sealed cans, or in their shipping containers.

CHEMICAL AMMUNITION

As a rule, chemical ammunition such as hexachloroethane (HC), white phosphorous (WP), and incendiaries should be stowed in dry, well-ventilated enclosures on the upper decks, convenient for jettisoning in an emergency. The different types of chemical ammunition should, if practicable, be stowed separately. For some items, separate stowage is mandatory. If the quantity of chemical ammunition is large, separate stowage by type is mandatory, and in most instances, individual instructions for stowage will be issued by NAVSEASYSCOM. In cases where toxic gas ammunition is to be stowed afloat, NAVSEASYSCOM will supply specially trained personnel to handle and stow the ammunition. For specifics on the stowage of titanium tetrachloride (FM), sulphur trioxide plus chlorosulfonic acid (FS), auxiliary boosters and boosters, refer to OP 4 and *Rules and Regulations for Military Explosives and Hazardous Munitions,* CG-108 DOT-USCG.

Q20. Grenades and igniters should not be stowed under what circumstances?

ROCKET-TYPE AMMUNITION

Air-launched and surface-launched rockets will be discussed separately. The portion on temperature control, however, applies to both.

Air-Launched Rockets

Aircraft rockets, when shipped with head and motor in the same container, assembled or unassembled, should be stowed in their shipping containers in fixed ammunition-type magazines. Ready-service stowage for assembled aircraft rockets other than those received assembled should be specifically authorized by NAVSEASYSCOM.

Surface-Launched Rockets

Stowage of surface-launched rockets should be separate and unassembled in the shipping containers with the following exceptions.

1. Commanding officers may authorize ready-service stowage of assembled but unfuzed rockets in the original shipping containers when such containers are designed for, or permit, such stowage.
2. During wartime, the officer in tactical command may authorize any quantity of rockets required to be completely assembled and fuzed. Complete rounds should be pointed outboard when topside and should be in outboard compartments when belowdecks. This authority should not be interpreted as blanket authority for continuous ready-service stowage in noncombat areas or when the situation does not demand such measures.

Temperature Control

All data available indicates that new rocket propellant that has not been exposed to abnormal temperatures is as safe as new single-based smokeless powder. Since no shipboard surveillance tests by which to evaluate stowage conditions have been approved for rocket propellants, rocket ammunition should always be stowed so that the oldest will be fired first. The age of a lot is determined by the last assembly date and not by the length of time it has been aboard.

The temperature limitations and temperature control regulations for magazines containing rocket motors are the same as those for magazines containing smokeless powder, or as specified for the specific round.

MISCELLANEOUS AMMUNITION

Experimental explosives or ammunition should be stowed separately from all other explosives. Privately owned ammunition should be stowed in magazines appropriate for the particular type of ammunition.

SURFACE-LAUNCHED MISSILES

Surface-launched missiles are ready-service complete rounds of ammunition. They are stowed in specifically designed magazines and/or launcher cells. The complete missile is a mixture of mechanical, electrical, and electronic equipment, and several different explosives components. Regardless of where the missiles are stowed, the same safety precautions for explosive hazards in magazine areas should be observed in all types of missile stowage areas.

PERMISSIBLE STOWAGE OF AMMUNITION AND EXPLOSIVES

As you know, original ship's plans provide magazines for each type of ammunition required to be stowed and these plans should be followed. However, original ammunition stowage requirements may be modified which, in turn, may require mixed stowages of ammunition in the same magazine. In these cases the chart of permissible stowages, OP 4, chapter 3, table 3-1, should be used in determining the proper stowage combination.

STOWAGE OF EQUIPMENT IN MAGAZINES

Normally the stowage of any article other than ammunition or explosives in spaces designated as magazines is forbidden. This is true even though the magazines are not required for stowage of ammunition. An exception to this regulation has been made for small ships to permit supplies and equipage to be stowed in magazines providing:

1. No ammunition or explosives are stowed therein.
2. The original design of the magazine is not altered or the ammunition stowage equipment removed.
3. The space may be rendered usable as a magazine within 24 hours.
4. Ammunition is not consolidated in fewer magazines to make space available for inert material.
5. No highly flammable material is stowed.
6. The sprinkler system may be temporarily secured but must be maintained in an operable condition.

ANSWER TO QUESTION Q20.

A20. Within 5 feet of radio apparatus or antenna leads.

HANDLING TECHNIQUES

This section on handling techniques will point out some of the more important regulations, safety orders, and precautions to be observed in handling ammunition, as well as the handling equipment and methods that may be used when regular handling gear is not available.

The utmost care and prudence should be exercised in handling and transporting all kinds of ammunition and explosives by all personnel whose duties require handling of ammunition. Personnel in ammunition working parties are continually engaged in work with explosives and, as long as nothing occurs, are inclined to drift gradually into neglect of necessary safety precautions. Nothing but constant vigilance on the part of all officers and petty officers in charge will ensure steadfast observance of the rules and regulations that experience has taught to be necessary.

Safety precautions, rules, and regulations for handling explosives should be made the subject of frequent instructions. The necessity for strict compliance with these procedures should be so firmly emphasized to new personnel that they will become second nature in their application. Attention is especially invited to the fact that in the early stages of handling ammunition and explosives, experience was gained at a great price. There have been several serious explosions from the early 1940's through the present that serve as examples of what can happen when explosives are accidently detonated. Unfortunately, there were in most cases, no survivors to testify as to what actually happened. *Ordnance Safety Precautions, Their Origin and Necessity*, OP 1014, presents case histories of actual casualties that have occurred while handling and using ammunition and explosives. The purpose of OP 1014 is to impress naval personnel at all levels with the need for rigid adherence to all safety precautions, and the grave consequences of their violations.

The number of personnel allowed in the vicinity of explosives should (as far as is practicable, depending upon the requirements of the operation) be reduced to the minimum required to properly perform the work at hand. It frequently happens that unnecessarily large working parties are assembled for handling live ammunition. Every effort and known precaution should be taken to make ammunition safe for handling under all conditions. This rule should be strictly followed to restrict as much as possible the danger and extent of injury to personnel in case of accident. Remember, the number of personnel actually handling ammunition should always be reduced to a minimum to reduce the chances of accidents.

The loading and unloading of ammunition will not be covered in this training manual, since OP 4 and OP 5 devote a chapter to the proper safety handling procedures to follow for ammunition afloat and ashore.

Q21. A complete missile is a combination of what components?

RETURN OF SHIP'S AMMUNITION TO AMMUNITION ACTIVITIES

In spite of all surveillance and protective measures taken to preserve ammunition afloat, certain integral components of all ammunition are subject to deterioration and must be replaced or renewed through breakdown and renovation. Since the facilities and specially trained personnel required for such operations are not provided to forces afloat, these operations are authorized only at shore-based ammunition activities and certain mobile ammunition evaluation reconditioning units (MAERUs) under the cognizance of NAVSEASYSCOM.

Through experience and quality evaluation, NAVSEASYSCOM has set definite age limits on most types of ammunition. Ammunition issued to forces afloat will have an expected serviceable period afloat. It is the responsibility of the ammunition activity to ensure that only serviceable ammunition is issued to forces afloat or revised whenever ammunition is put ashore during routine yard overhauls.

NORMAL RETURN OF AMMUNITION

NAVSEASYSCOM considers that the normal return of ammunition during regularly scheduled major yard overhauls will prevent the stowage of unserviceable or dangerous ammunition afloat. Upon completion of yard availability, issues will be made to the ship from the ammunition activity's ready-service stock.

Gun Ammunition

All gun ammunition which has been on board ship for 5 years after assembly or reassembly should be returned to an ammunition activity for examination, test, and renovation during the ship's next major overhaul availability. In no case should these items remain aboard ship longer than 7 years after assembly or reassembly. All smokeless powder charges and cartridges which have been on board ship 3 years since renovation, should at the ship's next major overhaul availability, be returned for renovation. In no case shall charges remain aboard ship longer than 4 years without renovation.

Special Return of Ammunition

Ammunition may be reclassified as to its serviceability by NAVSEASYSCOM through the use of notices of ammunition reclassification (NARs). This reclassification, changing the expected service or shelf life of an item, is a result of the various inputs from quality evaluations, firing reports, or accident/incident reports. Reclassification of ammunition may require immediate disposal or turn in, suspension from use, or designated limited use of an item. Whenever a reclassification of ammunition reduces ammunition quantities below authorized allowance, serviceable ammunition should be requisitioned. The unserviceable and limited usage ammunition should be turned in to an ammunition activity.

Procedure for Returning Ammunition

Prior to offloading ammunition, the ship concerned should procure and follow the senior officer present afloat (SOPA) instructions pertaining to the offloading operations for that particular area. Also, contact with the activity concerned, usually base ordnance, should be made for confirmation of the SOPA instructions, thereby making changes that may be applicable to the existing instructions. Arrangements may also be made for a conference, at which time all details of the offloading procedure may be ironed out. This includes such items as time and place of offloading, types and amounts of ammunition on board, number of lighters or barges needed, and types and amount of handling equipment required for the safe offloading operation (skip boxes, safety slings, lifting jacks, etc.).

Applicable Publications

The *Navy Transportation Safety Handbook*, OP 2165, describes existing regulations pertaining to safe handling and transportation of ammunition, explosives, and other dangerous articles.

The *Catalog of Handling Equipment for Weapons and Explosives*, OP 2173, lists authorized handling equipment used afloat and ashore for conventional weapons, ammunition, and explosives, as well as guided missiles. It also lists the safety precautions and instructions pertaining to the safe operation and use of handling equipment.

HANDLING EQUIPMENT

The task of ammunition handling and explosive handling is enormous and, by nature, inescapably hazardous. Accidents arising in ammunition and explosives handling kill and injure personnel, and destroy essential equipment.

These accidents do not just happen. They are caused by carelessness or unfamiliarity with the use and limitations of handling equipment, as well as relaxation or failure in observance of safety precautions, orders, and regulations.

When ammunition is being embarked from a ship at sea or in port, all safety precautions, orders and instructions should be strictly observed.

Cargo Nets

When ammunition is being embarked or discharged from a ship in port, a cargo net should be rigged between the ship and the dock or between the ship and the ammunition lighter to catch any ammunition that may be dropped.

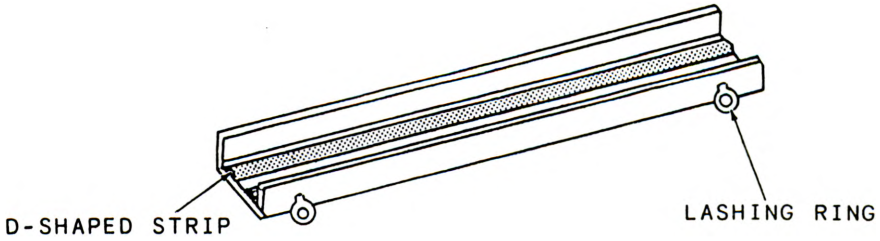
Cargo nets should not be used for transferring explosives and ammunition except to enclose a pallet, skip board, or tray. In hoisting or lowering containers with cargo nets, a rigid wooden platform should be fitted in the net upon which the container can be placed.

Ammunition Slides and Chutes

An ammunition slide (fig. 11-1) is constructed of smooth-planed boards not less than 1-inch thick with sides of the same material 4-inches high.

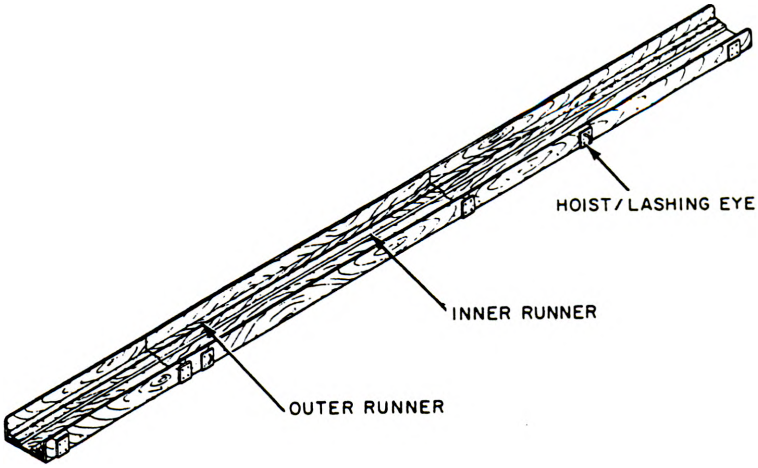
ANSWER TO QUESTION Q21.

A21. Mechanical, electrical, and electronic equipment; and explosive components.



53.312

Figure 11-1.—Ammunition slide.



53.313

Figure 11-2.—Ammunition chute.

The assembly is made with brass screws only. D-shaped wooden strips run lengthwise on the inner face of the chute. They are fastened to the upper surface of the slide by glue and wooden dowels extended through the bottom of the chute. A lashing ring at each corner of the chute secures it during use.

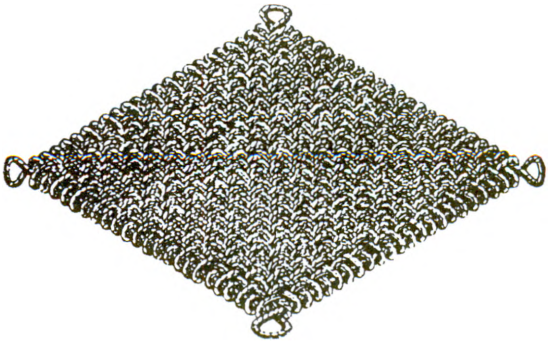
The ammunition slide is used to move projectiles and powder tanks to a lower level. Cargo mats or other forms of dunnage are used at the bottom of the slide. The ammunition slide is also used at shore stations.

The ammunition chute (fig. 11-2) consists of a plywood base and sides with inner and outer runners reinforced with steel straps. Two hoisting/lashing eyes are attached to each side to facilitate positioning and handling. The wood surfaces are treated with preservative and varnished.

The ammunition chute is used to transfer tanked and boxed destroyer-type ammunition between combat ship and dockside. Cargo mats or other forms of dunnage are used at the bottom of the chute.

Mats

The cargo mat (fig. 11-3) is a closely woven mat having no openings or mesh. The mat is



5.61.4

Figure 11-3.—Cargo mat.

constructed of 3-inch coil, which is a coconut hush fiber rope. The mats come in two sizes—6-feet square and 4-feet square. The mats have looped eyes on each corner for lifting.

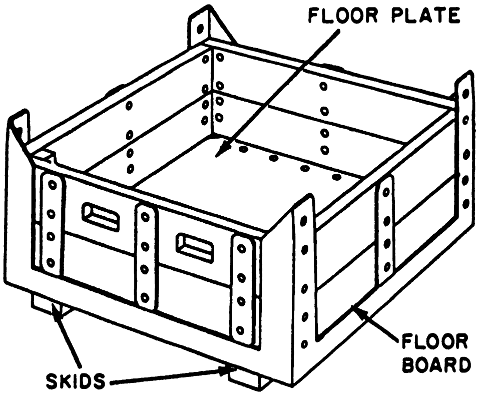
The mat is used aboard ship and at shore stations. It is used also inside cargo nets or skip boxes for the protection of the cargo. It is used to cushion the landing of a draft or material that is transferred on a slide.

Skip Box

The cargo handling box (skip box)(fig. 11-4) is made of wood except for the iron corner angles and stiffeners. This type of handling device is ideal for handling ammunition that is light enough to be handled by hand. The cargo handling skip box is used aboard ship and at shore stations. The heavy timber skids underneath permit the use of forklift trucks or slings to handle the box.

Pallet Adapters

The Mk 11 Mod 1 top spacer used with the Mk 11 Mod 1 bottom spacer (fig. 11-5) makes a complete pallet adapter for handling rocket heads and projectiles. The top and bottom spacers are fabricated of steel wire. The bottom spacer has 12 recesses, each of which holds the base of a projectile. The top spacer has 12 equally spaced holders to receive and hold the noses of the projectiles in a vertical position. The top spacer is reversible, one side being for rocket heads and the other for projectiles. There is a lifting link on each side of the top spacer.



5.61.1

Figure 11-4.—Skip box.

The Mk 11 Mod 1 pallet adapter is used aboard ship and at shore stations, and will handle a unit load of twelve 5″/54 projectiles. It will also handle twelve 5″ rocket heads. To secure the load on a 40 × 48-inch pallet, flat steel strapping should be used.

The Mk 16 Mod 0 pallet adapter (fig. 11-6) is a complete pallet adapter consisting of a top frame, rear frame, and front frame. It is used aboard ship and at shore stations and is capable of handling a capacity load of thirty-nine 5″/54 cartridge tanks. To secure the load on a pallet, flat steel strapping should be used.

SPECIAL HANDLING REGULATIONS FOR BULK EXPLOSIVES AND GUN-TYPE AMMUNITION

Extreme care must be taken in handling black powder, smokeless powder, or other bulk explosives since they are highly flammable and sensitive to friction, shock, sparks, heat, and static electricity. Only nonsparking tools shall be used to open containers of these explosives. The special handling instructions prescribed in the paragraphs that follow should be observed when handling gun-type ammunition.

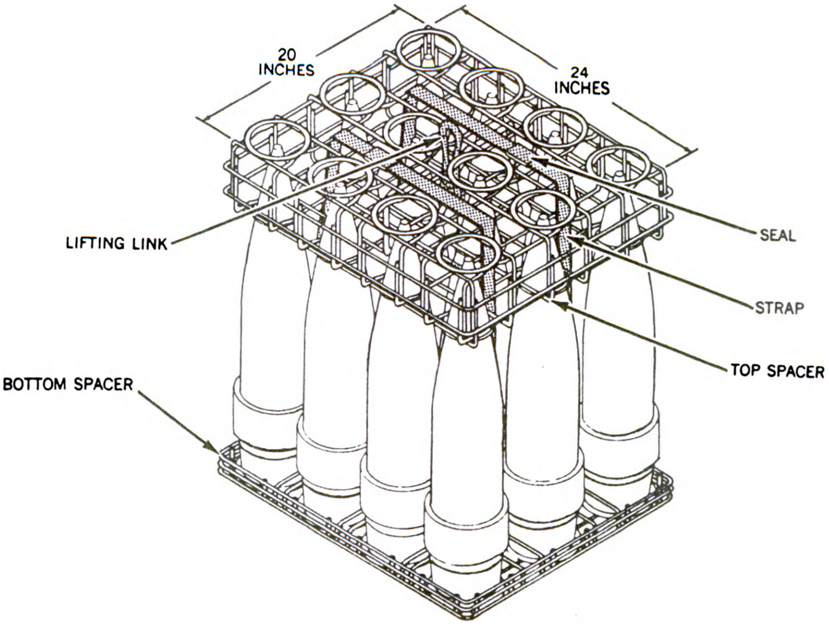
Projectiles

Load projectiles, whether unpacked, grommeted, crated, palletized, or packed should be carefully handled and stowed to avoid detonation or damage to rotating bands, bourrelets, points, caps, windshields, covers, fuze threads, painting, and identification markings. They should be handled by trucks, carriers, and slings. When rolling is the only available means of moving, protect projectile bodies, windshields, and copper rotation bands and guard against arming the fuze assembled in the projectile.

Projectiles should not be rolled on the ground, concrete floors, or steel decks, but may be rolled on dunnage boards not less than 1-inch thick.

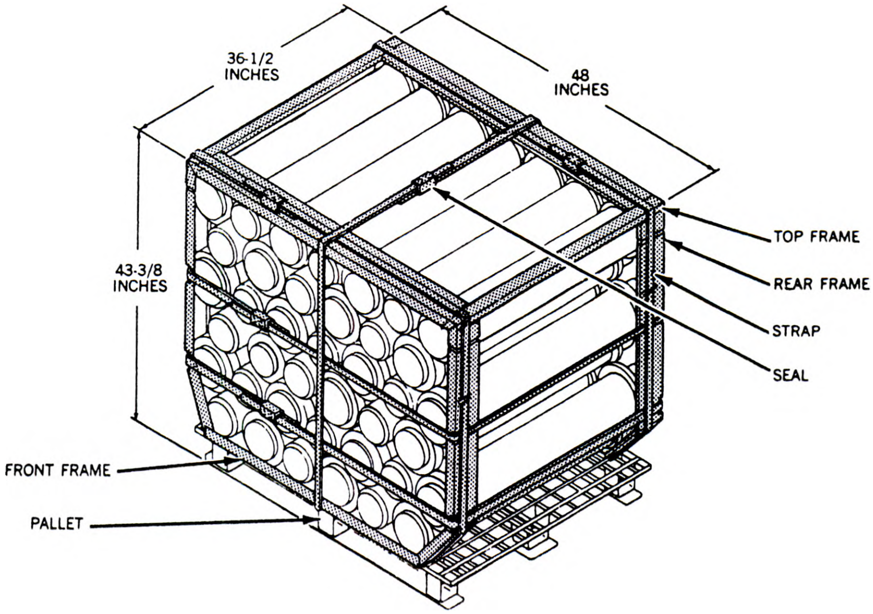
When a loaded and fuzed projectile is dropped 5 feet or more, it should be set aside, tagged, and turned in to an ammunition activity at the first opportunity—or dumped in deep water at the discretion of the commanding officer.

Projectile handling slings that support part of the weight of the projectile on the cap or windshield should not be used on armour-piercing projectiles or on common projectiles fitted with windshields.



123.53(53c)A

Figure 11-5.—Mk 11 Mod 1 pallet adapter.



123.53(53c)B

Figure 11-6.—Mk 16 Mod 0 pallet adapter.

Never slide projectiles down a slide without using a restraining line. The base of the projectile should be toward the lower end of the slide.

Detonator, fuze, booster cavities, and fuze threads should be kept free of all foreign matter except for a light film of specified lubricating preservatives.

Powder Tanks and Cartridge Tanks

Powder tanks containing bag charges should not be rolled or dropped. The necessary handling operations should be performed by carrying the filled tanks by hand, lift truck, or handtruck, being careful to prevent internal movement and possible ignition of the charge within the tank by static electricity. When lifting and moving such tanked charges, the bottom of the tank should be held lower than the top at all times.

Tanks containing fixed cartridges or separate loaded propelling charges should be handled carefully to prevent misalignment damage to the round or destruction of close tolerance dimensions. They may be handled with roller conveyors, chutes, or trucks as long as precautions against shocks are observed. Care should be exercised to avoid denting the thin-walled body, opening the body seams, or loosening the top or bottom rings, thereby permitting exposure of the powder to the atmosphere.

When a tank containing a fixed cartridge is dropped a distance of 5 feet or more, the tank and its contents should be set aside, carefully marked, and turned in to an ammunition activity at the first opportunity—or dumped in deep water at the discretion of the commanding officer.

Explosive Components

Fuzes, boosters, and detonators are loaded with explosives which are sensitive to shock, heat, and friction and must be handled with care at all times.

Every effort should be made to keep component containers sealed airtight when so packed and to limit their exposure to the atmosphere.

Containers of explosive blasting caps and fuzes should not be left uncovered and must be in the custody of authorized personnel at all time.

Wooden containers in which explosive components are packaged should be opened carefully using only approved spark-resistant tools. A wire, nail, or sharp instrument should **NEVER** be used to pry open the container.

Small Arms

It cannot be emphasized too strongly that inadvertent and improper use of small arms and small arms ammunition has resulted in numerous casualties. Invariably, the basic cause of each casualty is carelessness.

Cartridge cases should not be polished. However, corrosion, moisture, and dirt should be wiped off. The ammunition should be protected from shock which might dent it or fire the primer.

Ammunition should not be broken down except to make necessary examinations or when preparing ammunition for target practice or action. Small arms ammunition should not be opened until the ammunition is required for use. No reworking, overhaul, or modifying of any live-loaded ammunition or component is permitted on board ship.

Q22. Ammunition may be reclassified through the use of what document from NAVSEASYSCOM?

Q23. What is the reason for rigging a cargo net between the ship and pier during handling evolutions?

Q24. What two sizes of cargo mats are available for use with ammunition?

Q25. The Mk 11 Mod 1 pallet adapter is capable of holding how many rounds of 5"/54 ammunition?

SAFETY PRECAUTIONS FOR INDUSTRIAL HANDLING EQUIPMENT

The safety precautions and instructions pertaining to the safe operation and use of ammunition and explosives handling equipment prescribed in this section, NAVSEAINST 5100.19, OP 4, OP 5, OP 1014, OP 3347, and the applicable safety manual for particular weapons should be strictly observed by all naval activities, afloat and ashore.

Forklift trucks, pallet trucks, platform trucks, crane trucks, and warehouse tractors and trailers (industrial materials handling equipment) are used in various ammunition and explosives handling operations. This type of equipment is designed to save time and labor in handling operations. However, improper and careless operation or use of this type of equipment causes accidents, which result in fatal or serious injury, damage to valuable supplies and equipment, and reduction in the efficiency of the handling operation. Therefore, it is imperative that the safety precautions and instructions prescribed for all kinds of industrial materials handling equipment be followed to the letter.

SUMMARY

As you have read thus far, ammunition handling and stowage includes a lot of study and practice. You should frequently refer to those reference publications listed within this chapter. Should the occasion arise where there is a hint of doubt in any portion of a planned evolution, use the publications. Once a loading/off-loading plan has been drafted, check it against the local directives. Ammunition compatibility and environmental controls should be double checked to eliminate last minute rushes to ensure that the required space for these items is available.

Once the ammunition evolution has begun, a vigilant watch by all personnel is a must. When handling ammunition and using handling equipment, remember a few key points:

Cargo nets should not be used alone for handling thin-walled ammunition items. A rigid platform or base upon which the ammunition can be stacked should be fitted into the net. The platform should be placed as near the exact center of the net as is practicable so that the load will hand-level when suspended. The platform should be such size that the net will extend well up around the load when hoisted. A heavy canvas should be placed inside the wire rope cargo nets to prevent sparks and to protect the ammunition. Hooks used in handling ammunition should be moused to prevent accidental unhooking. A snap-type cargo hook may be used in handling ammunition. Any cargo hook shall be unpainted to afford ready visual inspection. Never exceed the safe working load of any ordnance handling equipment.

Do not allow yourself to become overwhelmed by the amount of information required to plan any ammunition handling evolution. Take each step one at a time and make use of your years of experience and training. Eventually, the material covered in this chapter will be become second in nature and you will find planning an on-load/off-load is not as difficult as it may seem.

REFERENCES

Gunner's Mate G 3 & 2, NAVEDTRA 10185-C1, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1987.

Gunner's Mate G 1 & C, NAVEDTRA 10186-D2, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1989.

Rules and Regulations for Military Explosives and Hazardous Munitions, CG-108, Department of Transportation, 1972.

ANSWERS TO QUESTIONS Q22 THROUGH Q25.

A22. Notice of ammunition reclassification (NAR).

A23. To catch any ammunition that may be dropped.

A24. 6-foot and 4-foot squares.

A25. 12.

CHAPTER 12

ADMINISTRATIVE DUTIES

Now that you are preparing for that big step to GMG1, you can expect to become an administrator. There are inspections, tests, and checks to be made on equipment; logs and records to be kept; inventories to be taken; spare parts to ordered; training schedules to be created or modified; reports to be made; and various other paperwork jobs to be performed. This will become as much a part of your day as getting soaked with hydraulic fluid or climbing behind the EP2 panel to read wire runs. As you have learned in the past, with that extra chevron comes increased responsibility and accountability.

REPORTS

Several reports are required by OPNAV, NAVSEASYSCOM, type commanders (TYCOMs), and other interested commands or offices to keep them informed of the status of your equipment and how it is functioning. Most of these reports will be made by the weapons officer or the administrative assistants; however, much of the initial draft will be supplied by the leading petty officers of the department. OPNAVINST 5214.1 (Consolidated List of Recurring Reports Required by the Bureaus and Offices, Navy Department, from Operating Forces of the Navy) lists those reports that are required. This list does not include those reports required by the fleet, force, or type commanders.

TYPES OF REPORTS

All reports fall into one of the three following general categories:

1. Periodic reports. These reports require the same type of information at regular intervals (i.e., monthly or quarterly).
2. Situation (performance) reports. These reports are submitted whenever an action occurs requiring a report (i.e., major casualty of ordnance equipment).
3. Special reports. These are one-time reports, such as a report on inventory of a specific class or type of material held by operating forces at a specific time.

Gun Wear/Star Gauge Reports

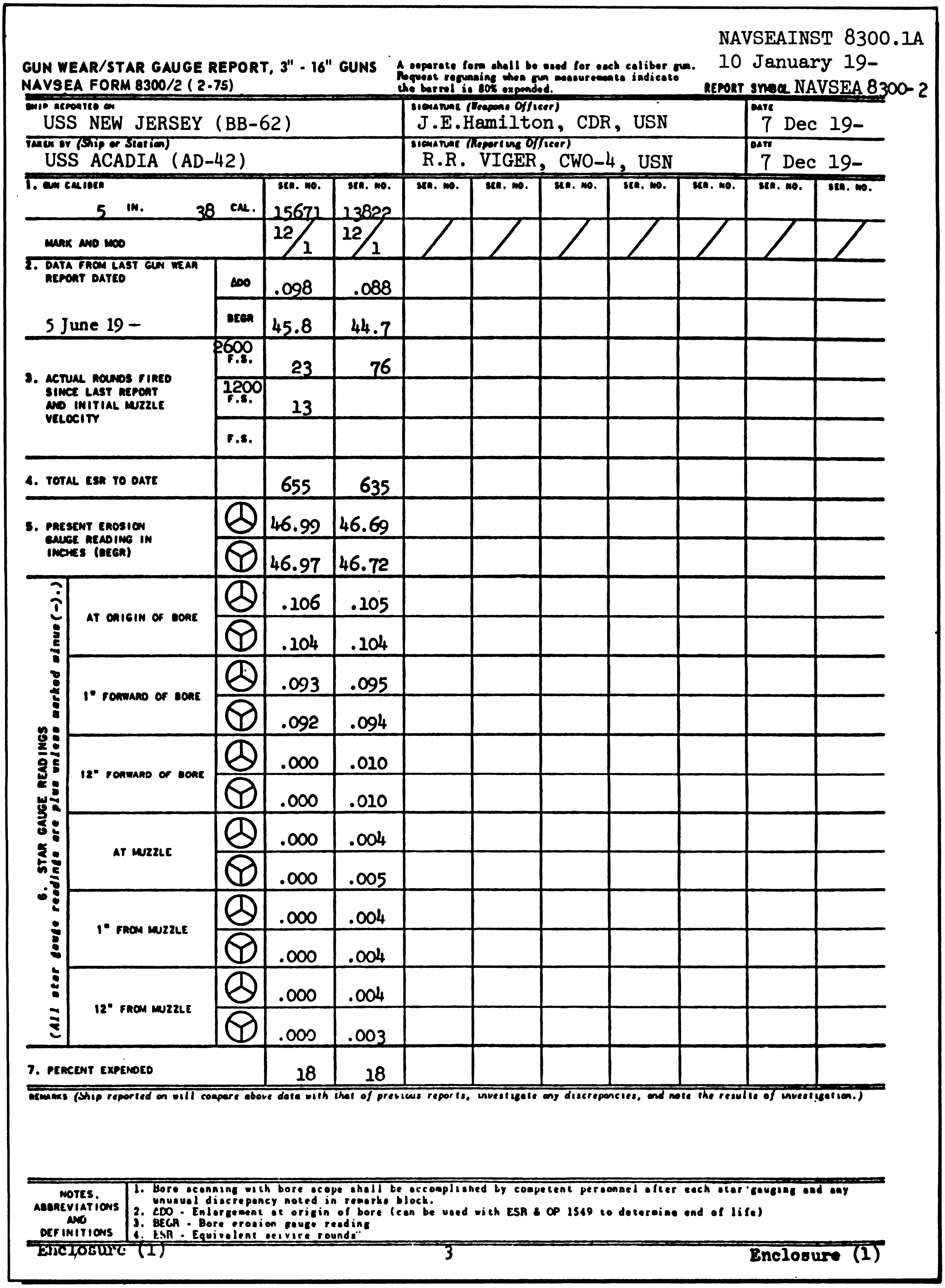
In compliance with NAVSEAINST 8300, all ships and stations with in-service 3″ to 16″ naval guns are required to submit annually a Gun Wear/Star Gauge Report, 3″ - 16″ Guns, NAVSEA 8300/2 (fig. 12-1).

As star gauges are not carried aboard most ships, star gauging should be requested from a tender or other available facilities, as near to the reporting date as feasible. Bore erosion gauge readings should be taken by the ship's company personnel on the same date that the star gauge readings are taken.

> **NOTE**: Ensure the rifling of the bore is clean of all deposits prior to star gauging.

The activity performing the inspection should use caution when taking both types of readings and in completing the gun wear/star gauge report; an erroneous entry could cause problems later. Submit the original report to the Commanding Officer, Code 8022 (MDS 49), U.S. Naval Ordnance Station (NOSL), Louisville, KY, 40214. Submit one copy each to the Commander, Naval Surface Weapons Center (NSWC) Dahlgren, VA, 22448; the type commander, and the activity requesting the star gauge measurements. The requesting activity's copy should be retained on board for file. The readings obtained for this report should also be submitted to your ship's fire control officer for the purpose of determining velocity loss correction for the battery.

When star gauge readings, or the projectile seating distance gauge (PSDG) readings, indicate that a barrel is 80% expended, the gun barrel should be replaced (regunned). Regunning is also necessary when the surface of the gun bore



NAVSEAINST 8300.1A
10 January 19-

GUN WEAR/STAR GAUGE REPORT, 3" - 16" GUNS
NAVSEA FORM 8300/2 (2-75)

A separate form shall be used for each caliber gun. Request regunning when gun measurements indicate the barrel is 80% expended.

REPORT SYMBOL NAVSEA 8300-2

SHIP REPORTED ON USS NEW JERSEY (BB-62)	SIGNATURE *(Weapons Officer)* J.E.Hamilton, CDR, USN	DATE 7 Dec 19-
TAKEN BY *(Ship or Station)* USS ACADIA (AD-42)	SIGNATURE *(Reporting Officer)* R.R. VIGER, CWO-4, USN	DATE 7 Dec 19-

1. GUN CALIBER 5 IN. 38 CAL.			SER. NO. 15671	SER. NO. 13822	SER. NO.	SER. NO.	SER. NO.	SER. NO.	SER. NO.	SER. NO.	SER. NO.
MARK AND MOD			12/1	12/1	/	/	/	/	/	/	/
2. DATA FROM LAST GUN WEAR REPORT DATED 5 June 19 –		ΔDO	.098	.088							
		BEGR	45.8	44.7							
3. ACTUAL ROUNDS FIRED SINCE LAST REPORT AND INITIAL MUZZLE VELOCITY		2600 F.S.	23	76							
		1200 F.S.	13								
		F.S.									
4. TOTAL ESR TO DATE			655	635							
5. PRESENT EROSION GAUGE READING IN INCHES (BEGR)		⊛	46.99	46.69							
		Ⓨ	46.97	46.72							
6. STAR GAUGE READINGS *(All star gauge readings are plus unless marked minus (–).)*	AT ORIGIN OF BORE	⊛	.106	.105							
		Ⓨ	.104	.104							
	1" FORWARD OF BORE	⊛	.093	.095							
		Ⓨ	.092	.094							
	12" FORWARD OF BORE	⊛	.000	.010							
		Ⓨ	.000	.010							
	AT MUZZLE	⊛	.000	.004							
		Ⓨ	.000	.005							
	1" FROM MUZZLE	⊛	.000	.004							
		Ⓨ	.000	.004							
	12" FROM MUZZLE	⊛	.000	.004							
		Ⓨ	.000	.003							
7. PERCENT EXPENDED			18	18							

REMARKS *(Ship reported on will compare above data with that of previous reports, investigate any discrepancies, and note the results of investigation.)*

NOTES, ABBREVIATIONS AND DEFINITIONS	1. Bore scanning with bore scope shall be accomplished by competent personnel after each star gauging and any unusual discrepancy noted in remarks block. 2. ΔDO - Enlargement at origin of bore (can be used with ESR & OP 1549 to determine end of life) 3. BEGR - Bore erosion gauge reading 4. ESR - Equivalent service rounds"

Enclosure (1) 3 Enclosure (1)

53.255

Figure 12-1.—Sample gun wear/star gauge report.

discloses serious deterioration, the rounds expended exceed the fatigue life expectancy, or when other criteria as listed in OP 1549, *Service Life of U. S. Naval Gun Barrels*, are met. Regunning is requested from NAVSEASYSCOM through the type commander.

Ammunition Report

Upon receipt of your shipsfill or partial load, an ammunition report is made to the Navy Ship's Parts Control Center (SPCC), Mechanicsburg, Pa., so that an accurate inventory of assets and expenditures of expendable ordnance items throughout the naval service can be maintained. The conventional ammunition integrated management system (CAIMS) is the CNO management system for ammunition. Complete instructions concerning this report are contained in OPNAVINST 8000.13, CINCPACFLTINST 8010.4, and COMNAVLOGPACINST 8015.1 (latest revisions).

Q1. What OPNAV instruction provides a listing of reports required of Gunner's Mates?

Q2. What are the three categories of reports?

Q3. What three instructions would you use for information on ammunition reporting?

FORMS

Forms are defined as any printed or duplicated material that requires you to fill in the blanks to give the form meaning. There are different forms for different purposes. Those most commonly used are the requisition forms for spare parts, record forms, and those used for reporting on ordnance material. It is policy to keep the required number of forms (paperwork) to a minimum. Forms should be used only to the extent that they serve their intended purpose. If you find that a form has insufficient space for your purpose, put the needed information in a letter and send it along with the completed form.

You can find full information on the distribution of forms, as well as the instructions for requisitioning them, in NAVSUP 2002. This publication lists all NAVSEA forms used by both fleet and shore activities.

SHIPBOARD GUNNERY LOGS AND RECORDS

The following material is intended as a guide for setting up and maintaining the required gunnery logs. Because these logs are standardized throughout the fleet, you will not have to learn new recordkeeping methods each time you are transferred from one duty station to another.

LOGS

A log is a book in which you keep a record of tests, overhauls, repairs, lacerations, maintenance, etc. You can make longhand entries in a type of stitched notebook, or enter them on a computer disk for later printing. If your log entries are prompt and accurate, they will later help you to discover both faulty design and faulty maintenance procedures. The 3-M Systems have replaced some, but not all, of the logs discussed in this chapter. On some ships, all of the logs are still in use and are required by many local commanders.

Of the various logs you will use, two of the most important are the battery logs and the fire control logs. Among the things you will list in these logs are data on:

1. List of major units or subassemblies or mounts, including mark, mod, and serial number. Put this list in the first pages of the log.
2. Performance and results of tests, checks, and measurements.
3. Special inspections.
4. Maintenance procedures not covered by checkoff lists, such as adding hydraulic fluid (state quantity and type); filling, flushing, or draining of hydraulic units; tightening bolts and nuts; adjusting; boresighting; and star-gauging.
5. Adverse effects of weather on material, maintenance, or operation.
6. Detailed description of casualties—giving name, mark, mod, serial number, and part number of the unit and parts involved; what happened; probable cause; how repaired; and steps taken to prevent recurrence.
7. Repairs. Brief summary of why repairs were necessary, and which parts were replaced.

8. Modifications. Record the number of the pertinent ORDALT, SHIPALT, field change, etc.

9. Tram readings, roller path compensator settings, and erosion indicator readings.

10. Drills and exercises.

11. Firings, including number of rounds fired, type, lot number, date, occasion, and equivalent service round; all kept by gun serial number.

12. Daily tests of cease firing alarms, lights, and transmission tests.

> NOTE: The importance of maintaining an alignment smooth log cannot be overemphasized. (Refer to the appropriate COMNAVSURFLANT/C8000.1 [LANT] or C8000.2A [PAC] gunnery notes for an explanation of what this log should contain.)

Small Arms Log

The small arms log should list the serial numbers of the small arms on board; and entries in the log should include casualties, repairs, modifications, results of inventories, and location of normal stowage.

Ballistics Logs

The ballistics log should be maintained to show ballistic variables. A separate log should be kept for each gun battery. A record should be made of the rounds fired by each gun, the star-gauge data, and bore-erosion data. This data should be recorded for each gun by serial number of the gun barrel. This log forms the basis for computation of equivalent service rounds (ESR). It can also be used to record any data affecting the ballistics of any particular gun in the battery. Do not record such routine items as cleaning and ship's drills. On days when no items of interest occur, just enter the date and your initials.

Magazine Temperature Log

The magazine temperature log is a day-to-day record of magazine temperatures. Make the daily entries for this record on a card which should be posted in the magazine in a conspicuous place near the thermometer. The card is kept on a monthly basis. It has spaces for recording the maximum and minimum temperature on each day of the month, and for the initials of the person recording the temperatures. Monthly, on completion of the magazine card, the temperatures must be transcribed into a permanent log. When temperatures exceed 100°F, the recordings should be transcribed to the permanent log in red ink, or made conspicuous by some other means.

In addition to the daily entries on the magazine card, keep a separate notebook for hourly entries of temperatures over 100°F. When such temperatures occur, the record should be transferred daily to a permanent log. Record the hourly temperatures in excess of 110°F, and a daily cumulative total of hours within each temperature range in excess of 110°F. Any magazine in which temperatures are consistently above 100°F should be reported to NAVSEASYSCOM.

AMMUNITION LEDGER

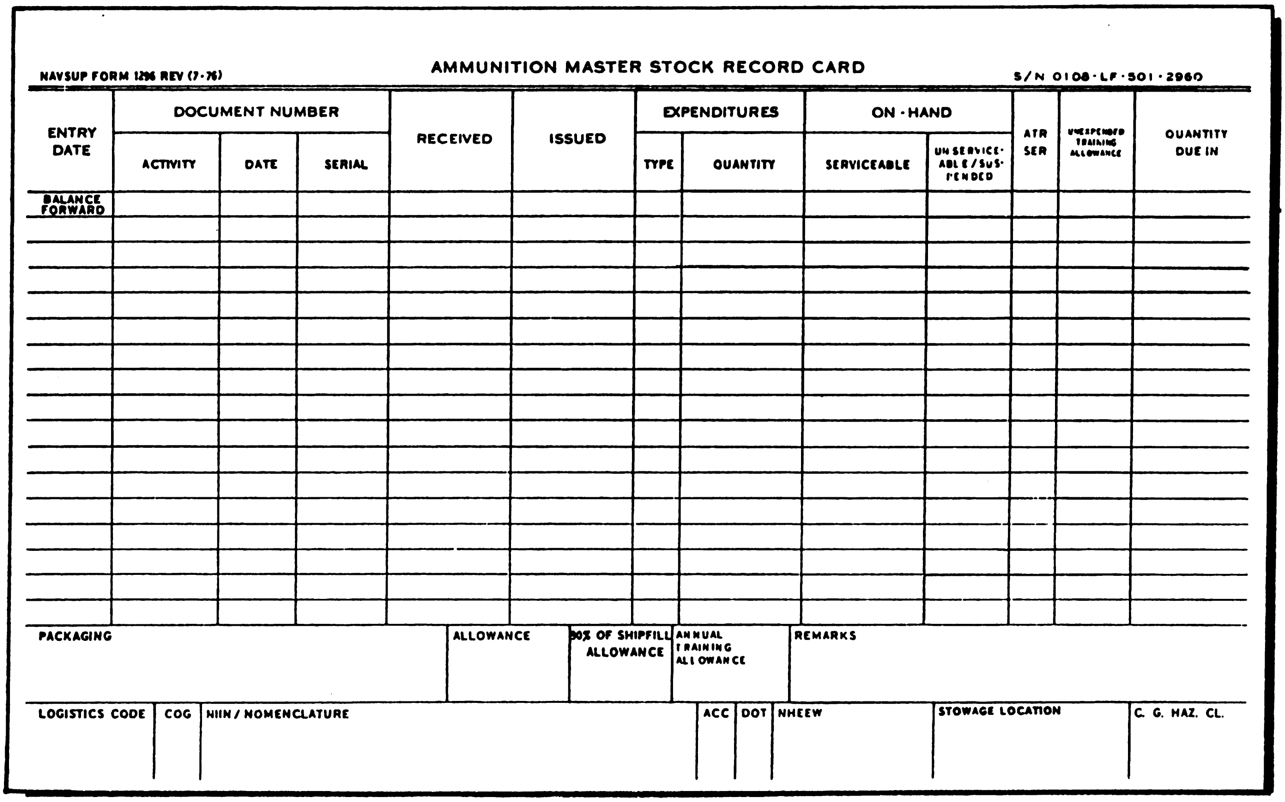
The ammunition ledger is a type of three-ring binder containing ammunition stock record cards for each type of ammunition aboard ship. There are two forms available for ammunition stock recording. An ammunition Master Stock Record Card, NAVSUP Form 1296 (fig. 12-2), and Ammunition Lot/Location Card, NAVSUP Form 1297 (fig. 12-3), should be maintained for every ammunition logistics code (NALC) carried on board. When transferring to a new stock record card, the existing stock record card should be retained for audit purposes. All entries should

ANSWERS TO QUESTIONS Q1 THROUGH Q3.

A1. OPNAVINST 5214.1.

A2. Periodic reports, situation reports, and special reports.

A3. OPNAVINST 8000.13, CINCPACFLTINST 8010.4 and COMNAVLOGPACINST 8015.1 (latest revisions).



NAVSUP FORM 1296 REV (7-76)

AMMUNITION MASTER STOCK RECORD CARD

S/N 0108-LF-501-2960

ENTRY DATE	DOCUMENT NUMBER			RECEIVED	ISSUED	EXPENDITURES		ON-HAND		ATR SER	UNEXPENDED TRAINING ALLOWANCE	QUANTITY DUE IN
	ACTIVITY	DATE	SERIAL			TYPE	QUANTITY	SERVICEABLE	UNSERVICEABLE/SUSPENDED			
BALANCE FORWARD												

PACKAGING

ALLOWANCE

80% OF SHIPFILL ALLOWANCE

ANNUAL TRAINING ALLOWANCE

REMARKS

LOGISTICS CODE

COG

NIIN/NOMENCLATURE

ACC

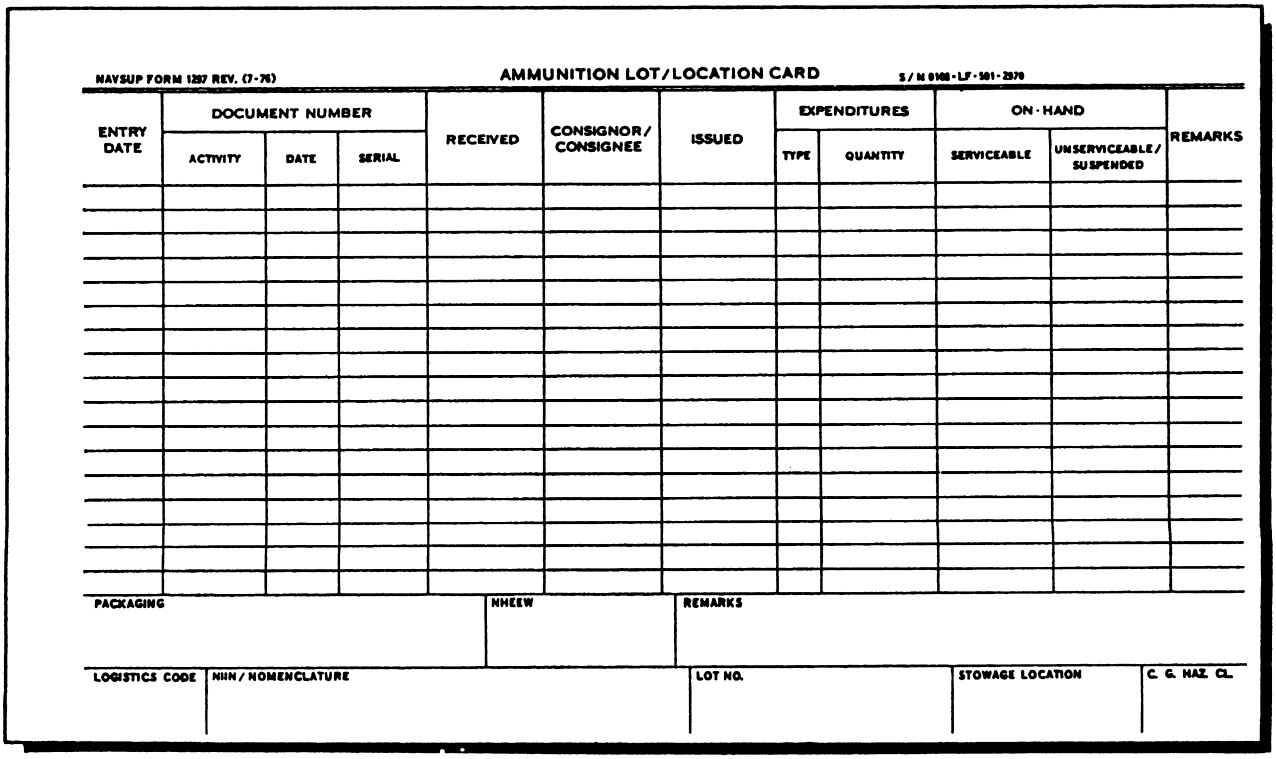
DOT

NHEEW

STOWAGE LOCATION

C. G. HAZ. CL.

Figure 12-2.—Sample NAVSUP Form 1296.



NAVSUP FORM 1297 REV. (7-76)

AMMUNITION LOT/LOCATION CARD

S/N 0108-LF-501-2970

ENTRY DATE	DOCUMENT NUMBER			RECEIVED	CONSIGNOR/ CONSIGNEE	ISSUED	EXPENDITURES		ON-HAND		REMARKS
	ACTIVITY	DATE	SERIAL				TYPE	QUANTITY	SERVICEABLE	UNSERVICEABLE/ SUSPENDED	

PACKAGING

NHEEW

REMARKS

LOGISTICS CODE

NIIN/NOMENCLATURE

LOT NO.

STOWAGE LOCATION

C. G. HAZ. CL.

Figure 12-3.—Sample NAVSUP Form 1297.

be posted promptly and in ballpoint pen. You will find the procedure and guidelines for preparing the ammunition stock recording cards in SPCCINST P8010.12 (latest revision).

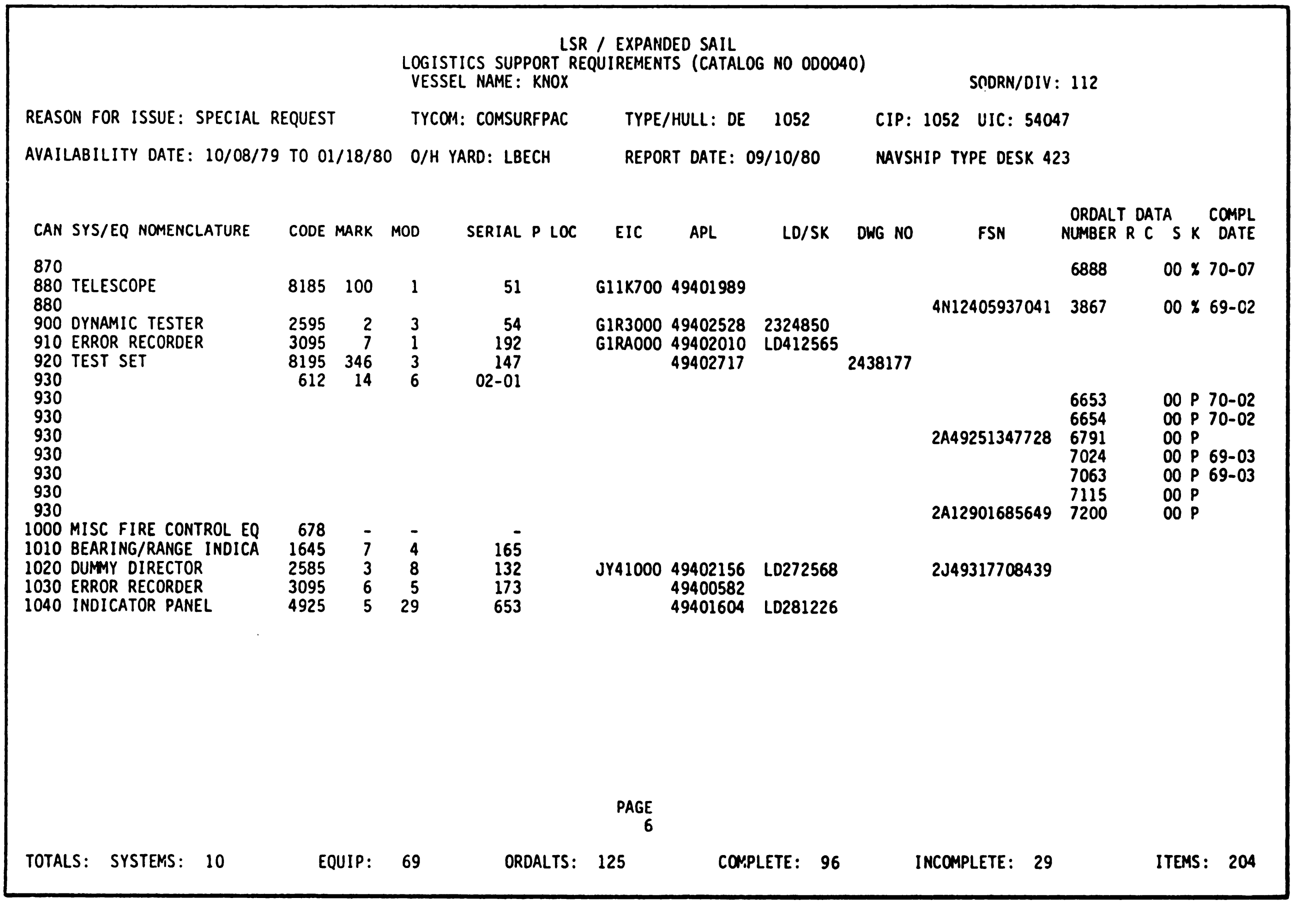
COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL)

The coordinated shipboard allowance list (COSAL) will eventually supersede virtually all individual allowance lists currently in use. The only material not included in COSAL will be medical material, hydrographic charts, ship's store merchandise, lubricants, and ammunition.

As a GMG, the parts of the COSAL that will be of interest to you are the sections that list the weapons systems, tools, and repair parts allowed for their maintenance. The type and quantity of repair parts allotted a ship were determined by studies of requirements in the past. Each ship is stocked accordingly.

The ordnance section of the COSAL is made up of three separate parts. The introduction gives complete information on the use of the COSAL (study this part carefully before using it). The stock numbers given in COSAL listings are national stock numbers (NSNs). When a piece of equipment is so new that repair parts have not been fully incorporated into the Navy supply system, these parts are listed by manufacturer's part number.

Part I of the COSAL is an index of all your equipment and equipage. Part II contains all the allowance parts lists (APLs) and allowance equipage lists (AELs) issued for your weapons equipment. Part III contains a stock number sequence list (SNSL) for the storeroom items and another list for the operating space items.



```
                                                           LSR / EXPANDED SAIL
                                         LOGISTICS SUPPORT REQUIREMENTS (CATALOG NO 0D0040)
                                          VESSEL NAME: KNOX                                             SQDRN/DIV: 112

REASON FOR ISSUE: SPECIAL REQUEST         TYCOM: COMSURFPAC      TYPE/HULL: DE   1052        CIP: 1052  UIC: 54047

AVAILABILITY DATE: 10/08/79 TO 01/18/80  O/H YARD: LBECH         REPORT DATE: 09/10/80       NAVSHIP TYPE DESK 423


                                                                                                                  ORDALT DATA    COMPL
CAN SYS/EQ NOMENCLATURE     CODE MARK  MOD      SERIAL P LOC    EIC     APL        LD/SK   DWG NO       FSN       NUMBER R C  S K  DATE

 870                                                                                                              6888       00 % 70-07
 880 TELESCOPE              8185  100     1         51        G11K700 49401989
 880                                                                                               4N12405937041  3867       00 % 69-02
 900 DYNAMIC TESTER         2595    2     3         54        G1R3000 49402528   2324850
 910 ERROR RECORDER         3095    7     1        192        G1RA000 49402010   LD412565
 920 TEST SET               8195  346     3        147                49402717            2438177
 930                         612   14     6      02-01
 930                                                                                                              6653       00 P 70-02
 930                                                                                                              6654       00 P 70-02
 930                                                                                               2A49251347728  6791       00 P
 930                                                                                                              7024       00 P 69-03
 930                                                                                                              7063       00 P 69-03
 930                                                                                                              7115       00 P
 930                                                                                               2A12901685649  7200       00 P
1000 MISC FIRE CONTROL EQ    678    -     -          -
1010 BEARING/RANGE INDICA   1645    7     4        165
1020 DUMMY DIRECTOR         2585    3     8        132        JY41000 49402156   LD272568          2J49317708439
1030 ERROR RECORDER         3095    6     5        173                49400582
1040 INDICATOR PANEL        4925    5    29        653                49401604   LD281226







                                                                 PAGE
                                                                    6

TOTALS:  SYSTEMS:  10          EQUIP:  69           ORDALTS:  125          COMPLETE:  96        INCOMPLETE:  29            ITEMS:  204
```

Figure 12-4.—Ship's armament inventory list (SAIL).

ORDNANCE ALTERATION (ORDALT)

The configuration control procedures for preparation and implementation of ordnance alterations (ORDALTs) to nonexpendable ordnance equipment is contained in NAVSEAINST 4130.9.

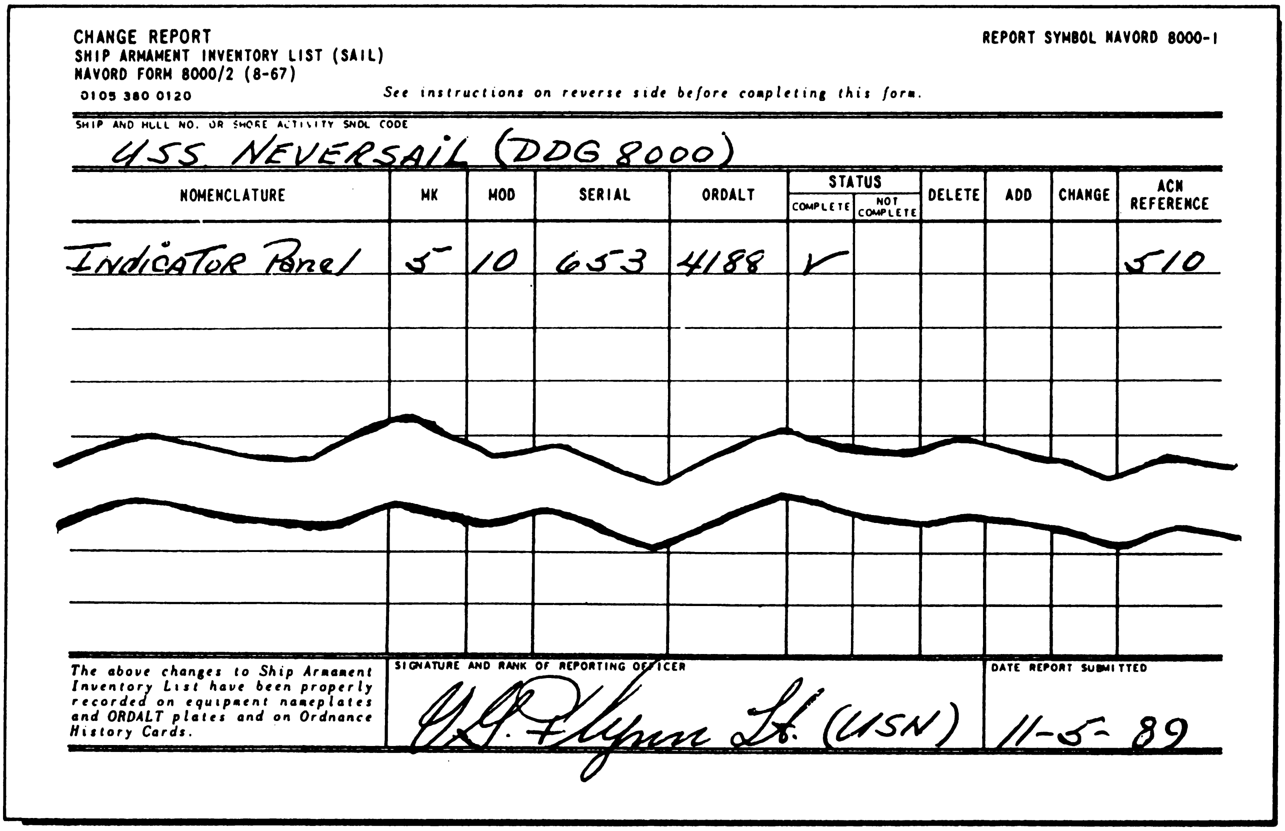
SHIP'S ARMAMENT INVENTORY LIST (SAIL)

The SAIL is a reporting system that furnishes a listing of installed shipboard ordnance equipment, including the equipment's ORDALT status, to NAVSEA and to all commands concerned with armament configurations. The SAIL is produced on data processing equipment in the format of the sample shown in figure 12-4.

Each ship is supplied with two copies of the SAIL. Prior to a scheduled overhaul, one copy of the SAIL should be marked to show any changes in the ORDALT status of the equipment since the list was published. Approximately 7 months prior to the scheduled overhaul, the updated list is sent to NAVSEACEN (Atlantic or Pacific). After the overhaul is completed, the SAIL is again marked and forwarded to the appropriate NAVSEACEN, indicating all deletions or additions to the equipment's ORDALT status that occurred during overhaul. Changes to the equipment, or to the ORDALT status of the equipment, made at times other than during an overhaul, are reported to the appropriate NAVSEACEN on NAVORD Form 8000/2. (See figure 12-5.)

Q4. As a Gunner's Mate, what might be considered two of your most important logs?

Q5. What magazine temperature would require an hourly log entry?



CHANGE REPORT
SHIP ARMAMENT INVENTORY LIST (SAIL)
NAVORD FORM 8000/2 (8-67)
0105 380 0120

REPORT SYMBOL NAVORD 8000-1

See instructions on reverse side before completing this form.

SHIP AND HULL NO. OR SHORE ACTIVITY SNDL CODE
USS NEVERSAIL (DDG 8000)

NOMENCLATURE	MK	MOD	SERIAL	ORDALT	STATUS		DELETE	ADD	CHANGE	ACN REFERENCE
					COMPLETE	NOT COMPLETE				
Indicator Panel	5	10	653	4188	✓					510

The above changes to Ship Armament Inventory List have been properly recorded on equipment nameplates and ORDALT plates and on Ordnance History Cards.

SIGNATURE AND RANK OF REPORTING OFFICER
J.G. Flynn Lt. (USN)

DATE REPORT SUBMITTED
11-5-89

180.121

Figure 12-5.—SAIL change report (NAVORD Form 8000/2).

Q6. What are the three parts of the COSAL?

Q7. For information on ORDALTS, you would refer to what NAVSEA instruction?

Q8. Changes to ordnance equipment during times other than overhauls are reported to the appropriate NAVSEACEN on what form?

REQUISITIONING AMMUNITION

The term "ammunition" as used here refers to all ammunition, ammunition components, other explosive devices, and pyrotechnics. DD Form 1348, an 80-column, single-line item document, should be used for requisitioning ammunition (unless naval message, telephone, or radio media are used). By single-line item, we mean that only one national stock number, Navy ammunition logistics code number, or other single-item identifier should appear on each DD Form 1348 requisition.

REQUISITIONING AMMUNITION WITH DD FORM 1348

DD Form 1348 is the basic request document used within the military standard requisitioning and issue procedure (MILSTRIP) system. MILSTRIP was developed by the Department of Defense to provide a common supply language and to provide a more effective system of supply operations within the military establishment. This system standardizes forms, formats, codes, procedures, and priority systems.

Depending upon the policy followed on your particular ship, ammunition requisitions may be either handled through the ship's supply department, or sent out directly from the weapons department. As a Gunner's Mate First Class, you should be familiar enough with the MILSTRIP system to be able to correctly requisition or turn in ammunition using the proper forms and format, and to understand the supply status reports on material ordered.

The following is an explanation of DD Form 1348 with brief instructions for filling it out. As you study this part, refer to the sample form in figure 12-6 to locate the blocks being explained. It would be to your advantage to fill out a blank DD Form 1348 as we go along:

BLOCK A—Enter the service designator code, unit identification code (UIC), and name of the activity to which the requisition will be submitted; e.g., N00109 WPNSTA YORKTOWN VA.

BLOCK B—Enter the service designator code, UIC, and name or requisitioning activity; e.g., V08943 UDT TWO ONE.

BLOCK C—Noun name of requested item; e.g., Grenade green smoke (This block is an optional entry).

BLOCK D, E, and F—Leave blank. (This is editing data and not used by the requisitioner.)

CARD COLUMNS 1 THROUGH 3—DOCUMENT IDENTIFIER: A three-digit code that identifies the basic type of administrative action; e.g., AOD identifies the document as a requisition for overseas shipment.

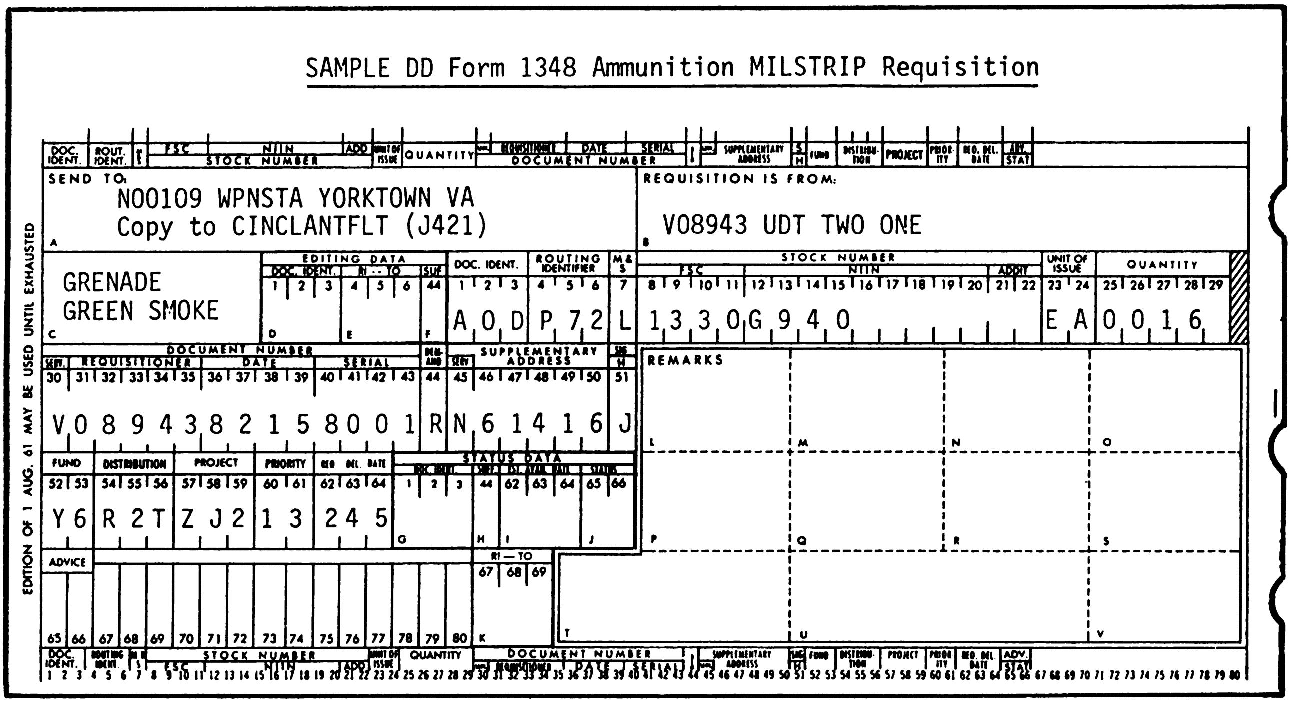
CARD COLUMNS 4 THROUGH 6—ROUTING IDENTIFIER: A three-digit code that identifies the activity that is to receive the requisition; e.g., P72 identifies WPNSTA YORKTOWN VA.

CARD COLUMNS 7 M and S CODE—MEDIA AND STATUS: A one-digit code to indicate type of status to be furnished; e.g., digit 3 means exception status to the requisitioner by mail. Exception status consists of information relative to any action taken by the supply source other than issue of the material; e.g., requisition

ANSWERS TO QUESTIONS Q4 AND Q5.

A4. Battery logs and fire control logs.

A5. 110°F.



SAMPLE DD Form 1348 Ammunition MILSTRIP Requisition

SEND TO:
N00109 WPNSTA YORKTOWN VA
Copy to CINCLANTFLT (J421)

REQUISITION IS FROM:
V08943 UDT TWO ONE

GRENADE
GREEN SMOKE

DOC. IDENT.: A0D
ROUTING IDENTIFIER: P72
M&S: L
STOCK NUMBER: 1330G940
UNIT OF ISSUE: EA
QUANTITY: 00016

DOCUMENT NUMBER: V08943 8215 8001
DEMAND: R
SUPPLEMENTARY ADDRESS: N61416
SIGNAL: J

FUND: Y6
DISTRIBUTION: R2T
PROJECT: ZJ2
PRIORITY: 13
REQ. DEL. DATE: 245

REMARKS

EDITION OF 1 AUG. 61 MAY BE USED UNTIL EXHAUSTED

43.24

Figure 12-6.—Sample requisition (DD Form 1348).

is rejected; requisition is referred to another activity for action; substitute item is furnished, etc. Normally, enter 3 in block 3.

CARD COLUMNS 8 THROUGH 22—STOCK NUMBER: A 15-digit space available for national stock numbers. It is permissible (and normally desired) when requisitioning ammunition to enter the DOD ammunition code instead of national stock number. Enter the DOD code for the item requested; e.g., 1330G940 identifies grenade green smoke.

CARD COLUMNS 23 AND 24—UNIT OF ISSUE: Enter the two-digit abbreviation for the unit of the item being requisitioned, as indicated in NAVSEA OD 12067; e.g., EA, RD.

CARD COLUMNS 25 THROUGH 29—QUANTITY: Enter the quantity required, with zeros in unused columns preceding the quantity required; e.g., 00016. If the quantity exceeds 99,999, additional requisitions should be submitted for the remainder.

CARD COLUMN 30—SERVICE CODE: e.g., V, Atlantic Fleet operating ships.

CARD COLUMNS 31 THROUGH 35—REQUISITIONER: Enter the 5- digit unit identification code (UIC) of the requisitioner.

CARD COLUMNS 36 THROUGH 39—DATE: Enter the four digits representing the Julian date on which the requisition is transmitted to the supply source. The Julian date consists of two elements—the last digit of the calendar year and the numeric consecutive day of the calendar year; e.g., 9181 represents 30 June 1989. The numeric consecutive day of the year may be found on most government issue calendar pads.

CARD COLUMNS 40 THROUGH 43—SERIAL: Enter a four-position serial number. Automated ships should use 5000 series serial numbers; nonautomated ships should use 8000 series serial numbers. Requisition serial numbers should not be duplicated on the same day.

CARD COLUMN 44—DEMAND: The demand code indicates whether the demand code R (recurring) when the item requisitioned is for shipfill, mission load or cargo load allowance; use N (nonrecurring) when the item requisitioned is clearly a one-time request.

CARD COLUMNS 45 THROUGH 50—SUPPLEMENTARY ADDRESS: Fleet units should use this field to indicate where the material requisitioned is to be received and loaded by entering the service code and UIC of the loading activity; e.g., N61416.

CARD COLUMN 51—SIGNAL: The signal code is used to identify the activity to which material is to be shipped and/or billed; e.g., J.

CARD COLUMNS 52 THROUGH 53—FUND CODE: The fund code is a two-character code that is used to cite accounting data on Navy requisitions; e.g., fleet units enter fund code Y6.

CARD COLUMNS 54 THROUGH 56—DISTRIBUTION: Distribution field entries serve a dual purpose and are mandatory entries. The first position indicates the monitoring activity and the other two positions indicate the cognizance (COG) symbol of the material being ordered. In card columns 55-56, enter the applicable COG symbol of the material being ordered; e.g., R2T.

CARD COLUMNS 57 THROUGH 59—PROJECT CODE: This code is a mandatory entry used to identify the purpose for which the item requisitioned is to be used; e.g., ZJ2.

CARD COLUMNS 60 AND 61—PRIORITY: Priority is a mandatory entry that expresses the relationship between the requisitioner assigned force/activity designator and the selected urgency of need designator; e.g., 13.

CARD COLUMNS 62 THROUGH 64—REQUIRED DELIVERY DATE: This is a mandatory entry. Enter the specific three-digit Julian date; e.g., 245.

CARD COLUMNS 65 AND 66—ADVICE CODE: This code is optional; it is used to provide the supply source with special instructions.

CARD COLUMNS 67 THROUGH 80—These columns are for supply use.

DATA BLOCKS L THROUGH V—REMARKS: Normally, requisitions will not contain remarks.

REQUISITIONING AMMUNITION BY NAVAL MESSAGE

When time is a factor, requisitions may be transmitted by naval message, telephone, or radio. Naval message requisitions should be prepared using the following guidelines:

1. The message should be sent to the supply source indicated in the routing identifier—block 2 of the MILSTRIP. Information copies should be provided to COMNAVLOGPAC or CINCPACFLT and the activity where material is to be delivered.
2. The message will be unclassified and the standard subject identification code (SSIC) should be N08012 for CINCPACFLT.
3. The subject will be ammunition MILSTRIP requisition.
4. Sample message:

AOE/N24/6/14101911/EA/00001/V04690/
8126/8025/R/N62 688/J/Y6/R8T/ZJ2/13/250/
2T

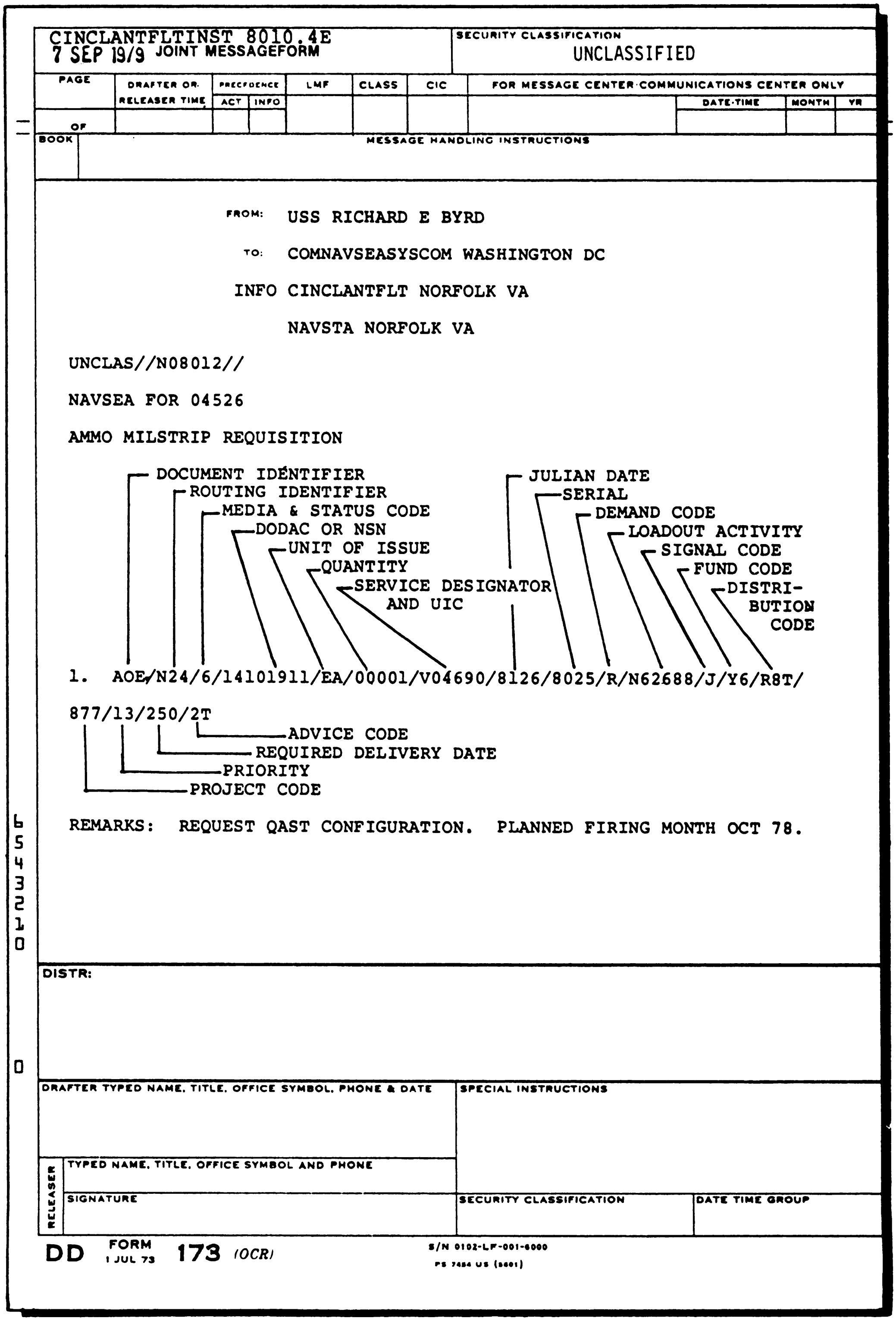
Refer to figure 12-7 as we break down the above message and identify each part. AOE, document identifier; N24, routing identifier; 6, media and status code; 14101911, DOD ammunition code or NSN; EA, unit of issue; 00001, quantity; V04690, service designator and UIC; 8126, Julian date; 8025, serial; R, demand code; N62688, loadout activity; J, signal code; Y6, fund code; R8T, distribution code; ZJ2, project

ANSWERS TO QUESTIONS Q6 THROUGH Q8.

A6. Index, APLs and AELs, and SNSL.

A7. NAVSEAINST 4130.9 series.

A8. NAVORD Form 8000/2.



CINCLANTFLTINST 8010.4E
7 SEP 1979

JOINT MESSAGEFORM

SECURITY CLASSIFICATION: UNCLASSIFIED

PAGE OF	DRAFTER OR RELEASER TIME	PRECEDENCE ACT	PRECEDENCE INFO	LMF	CLASS	CIC	FOR MESSAGE CENTER/COMMUNICATIONS CENTER ONLY DATE-TIME	MONTH	YR

BOOK

MESSAGE HANDLING INSTRUCTIONS

FROM: USS RICHARD E BYRD

TO: COMNAVSEASYSCOM WASHINGTON DC

INFO CINCLANTFLT NORFOLK VA

NAVSTA NORFOLK VA

UNCLAS//N08012//

NAVSEA FOR 04526

AMMO MILSTRIP REQUISITION

1. AOE/N24/6/14101911/EA/00001/V04690/8126/8025/R/N62688/J/Y6/R8T/

877/13/250/2T

REMARKS: REQUEST QAST CONFIGURATION. PLANNED FIRING MONTH OCT 78.

DISTR:

DRAFTER TYPED NAME, TITLE, OFFICE SYMBOL, PHONE & DATE	SPECIAL INSTRUCTIONS
RELEASER TYPED NAME, TITLE, OFFICE SYMBOL AND PHONE	
SIGNATURE	SECURITY CLASSIFICATION / DATE TIME GROUP

DD FORM 1 JUL 73 173 (OCR)

S/N 0102-LF-001-6000

PS 7484 US (6601)

31.47(123)

Figure 12-7.—Sample message format (DD Form 173).

code; 13, priority; 250, required delivery date; and 2T, advice code.

Requisitions transmitted verbally by telephone or radio should be relayed in exactly the same coded format. Normally written confirmation of these verbal requisitions are not required.

The answers to further questions you may have on MILSTRIP in regards to requisitioning ammunition can be found in volume II of the NAVSUP manual, NAVSUP publications 437 and 485.

TURN-IN OF AMMUNITION

When it is necessary to turn in ammunition, a DOD Single Line Item Release/Receipt Document, DD Form 1348-1 (fig. 12-8) will be prepared for each type of ammunition. An explanation of DD Form 1348-1 is shown in table 12-1.

Q9. What is the standard form for ordering ammunition?

Q10. Block C of a DD Form 1348 should reveal what information?

Q11. When requisitioning ammunition by message, what classification should be assigned?

Q12. When it is necessary to turn in ammunition, what DD form should be used?

3-M SYSTEMS

The 3-M Systems are the mainstay of managing maintenance aboard all ships of the Navy. Their purpose is to provide all maintenance and material managers with the means to plan, acquire, organize, direct, control, evaluate manpower and material resources expended, or planned for expenditure, in support of maintenance. In referring to "management," the term is used in its broadest sense, including the work center on the ship as well as Navy Headquarters in Washington.

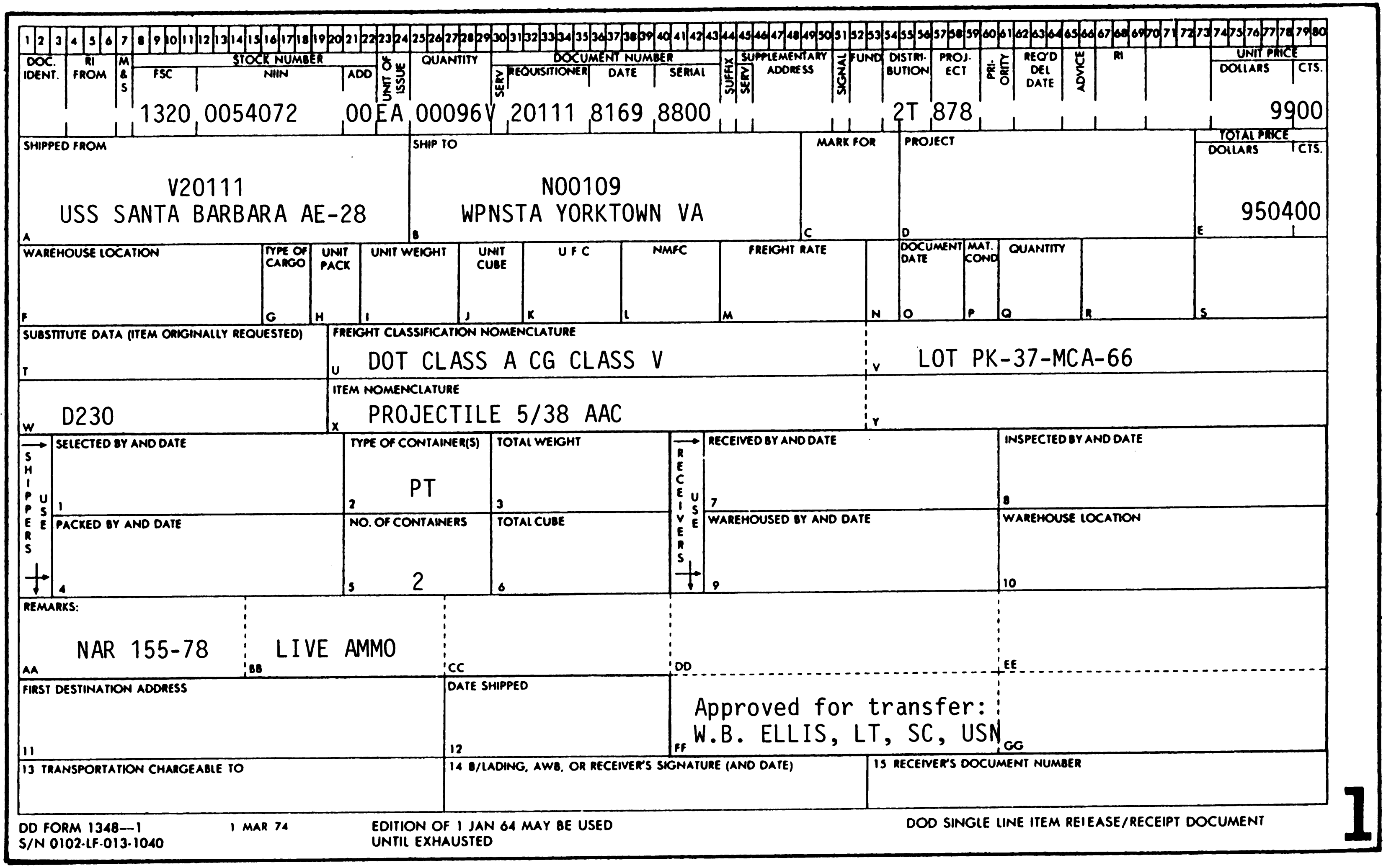
Table 12-1.—Explanation of DD Form 1348-1

Data block/ print position	Explanation
8-22	NSN, from NAVSEA OD 12067
23-24	Unit of issue
25-29	Quantity
30-43	Document number
55-56	Cognizance symbol of material
57-59	Project code
74-80	Unit price, from NAVSEA OD 12067
A	Service code, UIC, name and hull number of ship
B	Service code, UIC, and name of activity to receive material
E	Total extended price
P	Material condition code, from SPCCINST P8010.12, Chapter I, Section 2, Attachment C
U	DOT class and CG class
V	Lot number or serial number
W	DODIC/NALC
X	Noun name from NAVSEA OD 12067
2	Enter type of container used
3	Enter number of containers used
AA	Enter NAR number or other remarks to explain reason for turn-in
BB	Enter either LIVE AMMO or INERT AMMO as applicable
FF	For inert items only, enter CERTIFIED TO BE INERT
GG	Enter APROVED FOR TRANSFER

PLANNED MAINTENANCE SYSTEM (PMS)

PMS provides each user with a simple and standard means for planning, scheduling, controlling, and performing planned maintenance of all equipment. PMS is the most efficient means developed (to date) for using available maintenance resources.

PMS maintenance actions are the minimum required to maintain the equipment in a fully operable condition, within specifications. If performed according to schedule, these maintenance actions will provide the means to identify parts requiring replacement prior to



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

DOC. IDENT.	RI FROM	M & S	STOCK NUMBER FSC	STOCK NUMBER NIIN	STOCK NUMBER ADD	UNIT OF ISSUE	QUANTITY	SERV	DOCUMENT NUMBER REQUISITIONER	DOCUMENT NUMBER DATE	DOCUMENT NUMBER SERIAL	SUFFIX	SERV	SUPPLEMENTARY ADDRESS	SIGNAL	FUND	DISTRIBUTION	PROJECT	PRIORITY	REQ'D DEL DATE	ADVICE	RI		UNIT PRICE DOLLARS	UNIT PRICE CTS.
			1320	0054072	00	EA	00096	V	20111	8169	8800						2T	878						99	00

SHIPPED FROM
V20111
USS SANTA BARBARA AE-28
A

SHIP TO
N00109
WPNSTA YORKTOWN VA
B

MARK FOR C

PROJECT D

TOTAL PRICE DOLLARS CTS. 950400 E

WAREHOUSE LOCATION	TYPE OF CARGO	UNIT PACK	UNIT WEIGHT	UNIT CUBE	U F C	NMFC	FREIGHT RATE		DOCUMENT DATE	MAT. COND	QUANTITY		
F	G	H	I	J	K	L	M	N	O	P	Q	R	S

SUBSTITUTE DATA (ITEM ORIGINALLY REQUESTED) T

FREIGHT CLASSIFICATION NOMENCLATURE U DOT CLASS A CG CLASS V

V LOT PK-37-MCA-66

W D230

ITEM NOMENCLATURE X PROJECTILE 5/38 AAC

Y

SHIPPERS USE

1 SELECTED BY AND DATE

2 TYPE OF CONTAINER(S) PT

3 TOTAL WEIGHT

4 PACKED BY AND DATE

5 NO. OF CONTAINERS 2

6 TOTAL CUBE

RECEIVERS USE

7 RECEIVED BY AND DATE

8 INSPECTED BY AND DATE

9 WAREHOUSED BY AND DATE

10 WAREHOUSE LOCATION

REMARKS:

AA NAR 155-78

BB LIVE AMMO

CC

DD

EE

11 FIRST DESTINATION ADDRESS

12 DATE SHIPPED

FF Approved for transfer:
W.B. ELLIS, LT, SC, USN

GG

13 TRANSPORTATION CHARGEABLE TO

14 B/LADING, AWB, OR RECEIVER'S SIGNATURE (AND DATE)

15 RECEIVER'S DOCUMENT NUMBER

DD FORM 1348—1 1 MAR 74
S/N 0102-LF-013-1040

EDITION OF 1 JAN 64 MAY BE USED UNTIL EXHAUSTED

DOD SINGLE LINE ITEM RELEASE/RECEIPT DOCUMENT

1

43.24.1

Figure 12-8.—Sample release/receipt document (DD Form 1348-1).

failure. PMS procedures are, therefore, preventative in nature in that they are designed to prevent future equipment failures that might otherwise result in repeated corrective maintenance actions.

These PMS procedures and the periodicities in which they are to be accomplished are developed for each piece of equipment based on good engineering practice, practical experience, and technical standards. These procedures are contained on cards designated as maintenance requirement cards (MRCs). MRCs provide the detailed procedures for performing the preventative maintenance and state who, what, when, how, and with what resources a specific requirement is to be accomplished. Some MRCs have equipment guide lists (EGLs) accompanying them to serve as location guides for identical equipments (such as gauges, valves, CO_2 bottles, etc.) which are impractical to schedule individually for routine periodic preventative maintenance.

PMS procedures are developed by the activities and offices of the Naval Material Command that are responsible for the development and procurement of the systems/equipment for active, new construction, major conversion and activation ships, boats, and craft. PMS documentation (maintenance index pages [MIPs] and MRCs) is developed as part of the integrated logistics support (ILS) effort for all new procurements, reprocurements, alterations, and modifications of systems and equipment. The primary requirements for the PMS development activities are as follows:

1. PMS documentation should be developed in accordance to the current military specification (MIL-P-24534 [NAVY]) and critically reviewed in the sponsoring Navy organization prior to release to ensure that the planned maintenance requirements are current, technically correct, not excessive, and practical for fleet use.

2. PMS documentation approved by the Navy organization responsible for the equipment development and procurement shall be delivered concurrently with the installation of the applicable systems/equipment, or alterations.

A maintenance index page (MIP) contains a brief description of the requirements of the MRC(s) for each item of equipment, including the periodicity code, the estimated man-hours involved, the recommended rates and, if applicable, the related maintenance requirements. The MIPs for all equipment in a department are contained in a departmental master PMS record. This record also contains an index of effective MIPs, called a list of effective pages (LOEP). Additionally, each work center has a work center PMS record that is identical to the departmental master PMS record, except that it contains only those MIPs and LOEPs applicable to the work center.

The planning and scheduling of maintenance requirements are accomplished on the cycle, quarterly, and weekly schedules. Transferring maintenance requirements from MIPs for each work center contained in the departmental master PMS record and scheduling them on the cycle schedule creates the ship's overhaul-to-overhaul maintenance schedule. Quarterly and weekly schedules are prepared, using the cycle schedule as a guide. Maintenance requirements indicated on the weekly schedule are assigned to specific personnel for accomplishment. Scheduled maintenance actions are crossed over with an X when they are completed, and actions not completed are circled and arrowed to a new schedule date. Quarterly schedules are updated in the same manner.

The PMS Feedback Report (FBR), OPNAV Form 4790/7B, provides fleet maintenance personnel with the means to report discrepancies, problems, partial source data automation (PSDA)

ANSWERS TO QUESTIONS Q9 THROUGH Q12.

A9. DD Form 1348.

A10. Noun name of requested item.

A11. Unclassified.

A12. DD Form 1348-1.

requirements, and to request PMS software. All PMS feedback reports are sent to NAVSEACENs or TYCOMs (type commanders) based on the category of the FBR.

MAINTENANCE DATA SYSTEM (MDS)

MDS is the means by which maintenance personnel report corrective maintenance actions on specific categories of equipment. Information is retrievable from TYCOM and the maintenance support office department (MSOD) data banks for analyzing maintenance and logistics support problems, for the development of the CSMP, and for the generation of automated work requests for maintenance actions deferred for outside assistance.

It is a basic premise of the MDS that maintenance data should be recorded once and only once by fleet personnel and that the MDS data bank (not the maintenance activity) should thereafter provide information to all who have this correction, the MSOD data bank is distribution of maintenance and material data. Direct request to the fleet for data which is available from the MSOD imposes an unnecessary burden on the operating forces. It is that the policy of the Chief of Naval Material (CNM) that the Naval Material Command minimize request to the fleet for special data. However, if some such request are deemed essential, special request for data will include a phrase "The MSOD data bank has been queried and the data is not available."

From the 3-M Systems' central data bank maintained at MSOD, numerous reports are already programmed and available upon request by any command. These reports yield data concerning equipment maintainability and reliability, man-hour usage, equipment alteration status, material usage and costs, and fleet material condition. Many reports are produced periodically for users in both the Navy Shore Establishment and the operating forces.

From the deferred maintenance that is reported, a CSMP file is developed by the automatic data processing (ADP) facility designated by the TYCOM. From the CSMP file a series of computer reports is provided the ship and/or unit commander. These reports are also used by the TYCOM. The reports provide either a detailed or summary listing of deferred maintenance information in various format options. By-products of the CSMP include automated work packages, PREINSURV packages, etc. A package of automated work requests (AWRs) is generated by the ADP facility for each ship prior to overhaul and availability periods. These packages contain work requests for CSMP items appropriate to the designated repair activity as well as standard work requests for routine jobs performed during intermediate maintenance activity (IMA) and shipyard availabilities.

Prior to inspection by the Board of Inspection and Survey, a package of automated INSURV items is generated by the TYCOM from all deferrals listed in a CSMP file. These items are in a format similar to AWRs. After the INSURV board has screened these items and assigned priority numbers, if appropriate, the package is used to update the CSMP.

The usefulness of the MDS is dependent upon the accuracy, adequacy, and timeless of the information reported into the system. It is a system in which potential benefits are directly proportional to the efforts applied. Present programs for improving reliability, maintainability, and logistics support of fleet equipment are dependent upon conscientious adherence to reporting procedures.

Much of the fleet support effort resulting from the use of 3-M Systems' data is not always visible immediately to the fleet because of the time span required to test, evaluate, and implement engineering and design changes. Corrections to malfunctioning equipment through improvements in design often occur after the personnel who originally provided the information have been reassigned.

INTERMEDIATE MAINTENANCE ACTIVITY (IMA); INTERMEDIATE MAINTENANCE MANAGEMENT SYSTEM (IMMS)

The intermediate maintenance management system (IMMS) incorporates the computerized procedures used aboard tenders, repair ships, and repair bases/activities. These mechanized procedures are used to manage the planning, scheduling, production, and monitoring of the maintenance workloads of tended ships.

In summary, the purpose of the 3-M Systems is (1) to provide a tool to the fleet that can be used to manage, schedule, and perform maintenance; and (2) to provide information concerning fleet maintenance and maintenance support experience to organizations responsible for logistic support of the fleet. The Ships' 3-M Systems will operate in spite of meager resources and human error. These deficiencies are correctable. These systems, however, will definitely not work or survive in an atmosphere of indifference, especially in an atmosphere created by command indifference.

As a leading petty officer you should keep abreast of new developments and changes to the 3-M Systems. Details of the systems and changes related to them are available in the *Maintenance and Material Management Manual,* OPNAVINST 4790.4 (latest revision).

Q13. PMS procedures are based on what three factors?

Q14. Completed actions are annotated on the PMS schedule by what mark?

Q15. What manual should you reference for questions on the 3-M Systems?

PHYSICAL SECURITY OF CLASSIFIED MATERIAL

It is the responsibility of all personnel in the Navy to safeguard military information. Since you may often require the use of classified matter in your work, an understanding of the proper safeguards and control of such matter is essential.

The *Department of the Navy Information Security Program Regulations*, OPNAVINST 5510.1 (latest revision) is the controlling guide in safeguarding classified information. There is no adequate substitute for continuous day-to-day practice in the proper methods of handling classified material.

Classified information or material may be used only where the proper control facilities are available or under conditions adequate to prevent unauthorized persons from gaining access to it. The exact nature of security requirements depends on a thorough security evaluation of local conditions and circumstances. Security requirements must permit the accomplishment of essential functions while affording classified information appropriate security. The requirements that follow represent the *minimum* acceptable standards.

RESPONSIBILITIES OF CUSTODIANS

Custodians of classified material should be responsible for safeguarding the material at all times, and particularly, for locking classified material in appropriate security containers whenever it is not in use or under the direct supervision of authorized persons. Custodians should follow procedures which ensure that unauthorized persons do not gain access to classified information or material by sight or sound or other means. Classified information should not be discussed with, or in the presence of, unauthorized persons.

Classified information or material should not be removed from officially designated office or working areas for the purpose of working on such material during off-duty hours. Holding classified material for purposes involving personal convenience is not authorized unless specifically approved by the commanding officer or his/her designee. Prior to approval being granted, it must be determined that:

1. A compelling necessity exists.
2. The required physical security can be provided.
3. A complete list of the removed material will be left with the command.

CARE OF WORKING SPACES

Buildings and spaces containing classified information must be afforded the security measures necessary to prevent unauthorized personnel from gaining access to it. This includes the security measures necessary to prevent persons outside the building or spaces from viewing or hearing classified information.

CARE DURING WORKING HOURS

During working hours, precautions should be taken to prevent access to classified information by unauthorized persons. Among the necessary precautions are the following:

1. Classified documents, when removed from storage for working purposes, shall be kept under constant surveillance and face down or covered when not in use. Classified material cover sheets, such as OPNAV Form 5216/96, may be used for this purpose.
2. Classified information shall be discussed only when unauthorized persons cannot overhear the discussion.

3. Preliminary drafts, carbon sheets, plates, stencils, stenographic notes, worksheets, and all similar material containing classified information either should be destroyed by an approved method for destroying classified material *immediately* after they have served their purposes, or shall be given the same classification and safeguarded in the same manner as the classified material they produced.

4. Typewriter ribbons used in typing classified material should be protected in the same manner as required for the highest level of classification for which they have been used. Also, they must be destroyed as classified waste. The following are exceptions:

a. After the upper and lower sections have been cycled through the machine five times in the course of regular typing, all fabric ribbons may be treated as unclassified regardless of their classified use thereafter.

b. Any typewriter ribbon which remains substantially stationary in the typewriter until it has received at least five consecutive impressions may be treated as unclassified.

SECURING CLASSIFIED MATERIAL

Your command should require a security check at the end of each working day to ensure that all classified material is properly secured. The security check should determine the following:

1. All classified material is stored in the manner prescribed.
2. Burn bags are properly stored or destroyed.
3. The contents of wastebaskets that contain classified material have been properly stored or destroyed.
4. Classified shorthand notes, carbon paper, carbon and plastic typewriter ribbons, rough drafts, and similar papers have been properly stored or destroyed.
5. Security containers have been locked by the responsible custodians. The dial of the combination locks should be rotated at least four complete times in the same direction when securing safes, files, or cabinets.

The security check should be made a matter of record, with the record retained at least until the next security check is conducted. Optional Form 62 may be used for this purpose.

STORAGE OF CLASSIFIED MATERIAL

Commanding officers are responsible for safeguarding all classified material within their commands and for ensuring that classified material not in actual use by appropriately cleared personnel, or under their direct personal observation, is stored in the manner prescribed for that material.

As a leading Gunner's Mate, you should ensure that any weakness or deficiency found in containers being used for the protection of classified material is reported to the proper authority.

Because they increase the risk of theft, valuables should not be stored with classified material.

Containers should not have external markings that indicate the level of classified information stored within. For identification purposes however, the exterior of each container should bear an assigned number or symbol.

COMBINATIONS AND KEYS

Combinations to security containers should be changed only by individuals cleared for the highest level of classified material in the container. Combinations should be changed under any of the following circumstances:

1. When the container is first placed in use after procurement.
2. Whenever an individual knowing the combination no longer requires access.
3. When the combination has been compromised or the security container has been discovered unlocked and unattended.
4. At least annually, unless a more frequent change is dictated by the type of material stored therein.
5. When the container is taken out of service. Built-in combination locks should be reset to the standard combination 50-25-50. Combination padlocks shall be reset to the standard combination 10-20-30.

In selecting combination numbers, multiples of 5, simple ascending or descending arithmetical series, and personal data such as birthdates and serial numbers should be avoided. The same combination should not be used for more than one container in any one component of the command.

The combination of a vault or container used for the storage of classified material should be assigned a security classification equal to the highest category of the classified material authorized to be stored in it.

Knowledge of, or access to, the combination of a vault or container used for the storage of classified material should be given only to those appropriately cleared persons who are authorized access to the classified information stored therein and have an operational use for it.

Records of combinations should be sealed in an envelope (OPNAV Form 5511/2 may be used) and kept on file by the security manager, duty officer, communications officer, or other person designated by the command.

When key-operated high security padlocks are used, the keys should be controlled as classified material of a classification equal to the classification of the material being protected, and should be safeguarded as follows:

1. A key and lock custodian should be appointed to ensure proper custody and handling of keys and locks used for protecting classified material.
2. A key and lock control register should be maintained to identify keys for each lock and their current location and custodian.
3. Keys and locks should be audited each month.
4. Keys should be inventoried with each change of custodian.
5. Keys should not be removed from the premises.
6. Keys and spare locks should be protected in a security container.
7. Locks should be changed or rotated at least annually, and should be replaced upon loss or compromise of their keys.
8. Master key is prohibited.

A record should be maintained for each vault, secure room, or container used for storing classified material. This record should show the location, and the names, home address, and home telephone numbers of persons having knowledge of the combination to the storage facility. GSA Optional Form 63 or OPNAV Form 5511/30 may be attached to the container to identify the custodian. When Optional Form 63 is used, a privacy act statement should be provided to those listed and their consent obtained before any prominent display is allowed.

Electrically actuated locks (e.g., cipher and magnetic strip card locks) do not afford the degree of protection required for classified information and should not be used as the locking device on security containers.

REPRODUCTION OF CLASSIFIED INFORMATION

Classified information is normally prepared, printed, and reproduced by Department of the Navy or Department of Defense facilities. When this is not possible, the preparation, printing, and reproduction of classified information is authorized by the following:

1. For Top Secret material:
    a. Only as specifically approved by the Director, Navy Publications and Printing Service.
2. For Secret and Confidential material:
    a. Government Printing Office
    b. In commercial facilities having an active facility clearance at least as high as the classified information to be processed and obtained in accordance with the requirements of the Department of Defense industrial security regulation and when specifically approved by the Director, Navy Publications and Printing Service.

Printing, Duplicating, and Reproduction of Classified Material

The Director, Navy Publications and Printing Service, is responsible to the Commander, Naval

ANSWERS TO QUESTIONS Q13 THROUGH Q15.

A13. Good practice, practical experience, and technical standards.

A14. X.

A15. OPNAVINST 4790.4.

Supply Systems Command, for the technical guidance and distribution of all Navy classified publications.

From a security viewpoint, the printing, duplication, or reproduction of classified material poses many problems; (1) it contributes to the increasing volume of classified material; (2) it permits quick and easy production of uncontrolled material containing classified information; (3) the equipment or processes require care or special procedures to prevent or eliminate latent impressions or offset versions of the classified information; and (4) a quantity of excess and waste material is produced, which can contribute to compromise of the classified information. Therefore, local commands must require close supervision and careful control of all reproduction facilities under their jurisdiction. Of particular importance is the need for controlling and supervising the use of office copying machines for the printing, duplication, or reproduction of classified material and to assure the proper recording and safeguarding of the classified material reproduced by such means. In no event, however, should classified material be reproduced without the approval of competent authority.

Destruction of Classified Material

For instructions regarding the destruction of classified material, refer to OPNAVINST 5510.1 (latest revision).

Q16. What publication is considered the controlling guide in safeguarding classified information?

Q17. What OPNAV Form could be used as a cover sheet for classified information?

Q18. Security checks are recorded on what form?

Q19. How often should keys and locks to security containers be audited?

PERIODIC INSPECTIONS—TYPES AND REQUIREMENTS

It should be safe to assume that you are totally familiar with the various types of internal shipboard inspections (those conducted by the CO or other officers of your own command), so we will cover only the external-type inspections here. By external, we mean any inspection conducted by an activity or command outside of your own command. There are three types of external inspections: (1) operational readiness, (2) material, and (3) administrative.

OPERATIONAL READINESS INSPECTION (ORI)

The operational readiness inspection (ORI) is usually conducted in the final stages of refresher training (REFTRA). The ORI evaluates the ship's offensive and defensive capabilities. A comprehensive battle problem is part of the ORI. ORI inspections are usually conducted by teams from the fleet training group, but may be conducted by representatives of the type commander at any time. Inspectors from either source will not be content with a broad determination of the ship's effectiveness in battle. In fact, a good part of the inspection consists of interrogating individual members of the crew. Questions are asked and simulated battle conditions are placed in effect to enable the inspectors to grade the individual's flexibility, versatility, and general training level.

MATERIAL INSPECTIONS

A material inspection can be conducted by the type commander at any time. All equipment in your charge is checked for proper operation, and to determine whether preventative maintenance measures are in effect. A Board of Inspection and Survey (INSURV) material inspection is also conducted at least once every 3 years. INSURV inspections are usually held before a shipyard availability period, and are apt to be even more exacting than the type commander's inspection. Material discrepancies should be noted in your CSMP on Deferred Action Form 4790/2K. A personal inspection file will be a good idea for you to keep for your own inspection discrepancies that can be corrected immediately by ship's force. They may, of course, be included in the department's inspection file.

ADMINISTRATIVE INSPECTION

An administrative inspection is a check of all administrative procedures, the availability of administrative materials, plus a spot check of equipment condition. The degree of the latter is at the discretion of the inspecting officer, and is related to an inspection of preventative maintenance procedures. The type commander's "admin" is the most involved, but the fleet training group also conducts an admin as a part of their arrival inspection. Don't forget, the most important aid in preparing for an admin inspection is the type commander's administrative checkoff list.

SUMMARY

In this chapter we have discussed the various reports, forms, logs, and records used throughout the Navy and various fleets. It is of the utmost importance, and to your benefit for you to understand the workings of the COSAL, SAIL, and ammunition requisitioning procedures. The 3-M Systems were designed to assist you in maintaining the highest degree of readiness obtainable. They have many advantages if used properly. The requirement for keeping a running log of deficient material is a great aid in maintaining your equipment in an inspection ready condition. As a last note, remember, while the security of classified material is the ultimate responsibility of the commanding officer, the responsibility starts at the lowest level in the chain of command.

REFERENCES

Gunner's Mate G 1 & C, NAVEDTRA 10186-D2, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1989.

ANSWER TO QUESTIONS Q16 THROUGH Q19.

A16. OPNAVINST 5510.1 (latest revision).

A17. OPNAV FORM 5216/96.

A18. Optional Form 62.

A19. Monthly.

CHAPTER 13

MAINTENANCE

Up to this point in your career, you have been the worker, or as we would prefer to call you, the "maintenance technician." Your main concern has been the routine maintenance on the gun required to keep it functioning as designed. As the leading Gunner's Mate (Guns), you are now to concern yourself more with managing these programs you have so faithfully supported. As an administrator, you need to know the source of all this maintenance information.

Maintenance can be defined as that operation (or that group of operations) by which an item or assembly is sustained in (or restored to) a functional condition. The need for maintenance is determined during normal operations under different environmental conditions. The degree of maintenance that may be required is determined by the availability of technically qualified personnel, by necessity, by the amount of time available, and by the extent of maintenance you are authorized to perform.

Under these constraints, you may be required to make the decision whether or not to replace a $25,000 piece of equipment, or to troubleshoot further. You might find the cause is nothing more than a burnt contact relay that can be repaired locally for virtually nothing.

To ensure proper operation after repair or replacement, at least five different types of adjustments to the equipment may be required. These adjustments include the critical tolerances of electrical, electronic, mechanical, hydraulic, and pneumatic parts/components. The proper methods, techniques, and safety practices used in performing all types of maintenance will ensure that the job will meet final inspection and test before normal operation.

Q1. What are the five types of component adjustments that may be required on your equipment after repair or replacement of parts?

MAINTENANCE SKILLS

In performing any type of maintenance, a Gunner's Mate requires specific information relating to the particular equipment to be maintained and repaired. He must also possess the required skills and knowledges that apply to the maintenance of a myriad of equipment. The information needed can be found in the particular system's OP, but skill and knowledge take many hours of dedicated training to develop and fine tune.

We can assume that you have developed those general skills by following the procedures as set forth in your personnel advancement requirements (PARs). As the LPO, you must be prepared to teach those skills to your subordinates. Your trainees will not be too impressed with a first class petty officer who can't take an ohmmeter reading or check the clearance of a microswitch. You must learn more about the overall and continuing plan of maintenance and the responsibilities of administration, as well as the technical duties in maintenance.

SCHEDULED MAINTENANCE

Scheduled maintenance prevents and detects failures, and maintains a high degree of operational readiness. Scheduled maintenance consists of inspection and test, cleaning, and lubrication procedures. These procedures are presented in the maintenance sections of equipment OPs and on separate maintenance requirement cards (MRCs). MRCs are cards that detail the procedures and equipment to use when performing maintenance tasks.

MAINTENANCE PLANNING

A study of the occupational standards shows that the GMG1 must be able to overhaul, repair, test, adjust, and record all authorized maintenance performed. Note that nearly all the knowledge factors are required at the GMG3 and GMG2 level, with exception of the principles of receiver-regulators, functions of fire control, and supply procedures. You are expected to have knowledge of the basic geometric layout for drawings and sketches, to be able to prepare freehand sketches, and to read and interpret diagrams and service instructions.

The success of any planned maintenance program depends upon the cooperation you receive at the working level. Your maintenance personnel need to understand how their day-to-day work of lubrication, cleaning, and similar routine upkeep helps prevent costly and time-consuming breakdowns and the subsequent hard repair work.

The responsibility of the GMG1 in administering the PMS and the MDS is described generically for PO1 in OPNAVINST 4790 (latest revision). Planning the daily maintenance work is your responsibility.

Q2. Where can you find the maintenance information pertaining to your system's maintenance?

Q3. What is the purpose of scheduled maintenance?

SYSTEM PREVENTIVE MAINTENANCE

Preventive maintenance components are built into some ordnance systems to help detect faults within the systems. One of these components is a ground detection indicator.

The ground detection indicator is a continuous monitoring system designed to detect a system ground. Since most control circuits in ordnance systems are powered by ungrounded 115-volt, 60 hertz, single-phase current, the first ground is not very important from an operational point of view. However, if the first ground is not discovered, and a second develops, the result could be an illogical and destructive sequence of system operation. The reason for this is that two grounds act as electrical conductor between the grounded components. When the ground detector indicates (by light or buzzer) that some of the control circuitry is grounded, you should determine the location and cause of the ground. The elimination of most grounds and potential grounds is good maintenance and housekeeping.

Q4. What is the purpose of the ground detection indicator?

ELECTRICAL AND ELECTRONIC SYSTEM MAINTENANCE

Electrical and electronic system maintenance is easily conducted when the proper procedures are followed. You should always follow the guidelines you are given in your system OPs, regardless of your experience level.

INTERLOCK SWITCHES

Most interlock switches require either monthly or quarterly checks to be sure that they are actuating and deactuating properly. In addition, some switches should be electrically checked periodically to determine whether they are making and breaking as required, and some switch circuits should be checked periodically for continuity.

Equipment-Mounted Interlock Switch Elements

Equipment-mounted interlock switches and solenoid-mounted interlock switch elements are

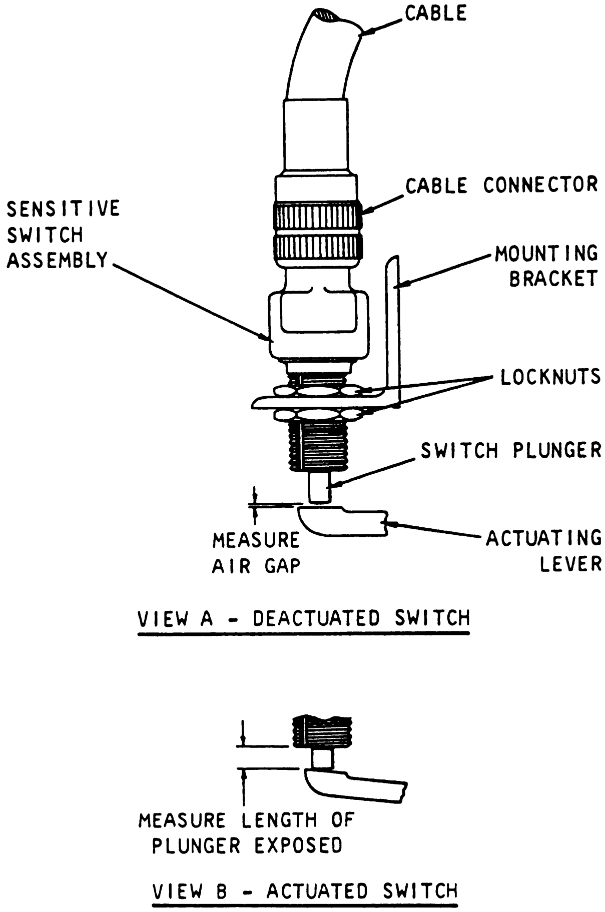
ANSWER TO QUESTION Q1.

A1. Electrical, electronic, mechanical, hydraulic, and pneumatic.

used in all gun mounts. Equipment-mounted switches are part of various gun loading and gun laying components, and indicate the status of those switch elements as an integral part of their respective solenoid assemblies. They indicate the status of solenoid position.

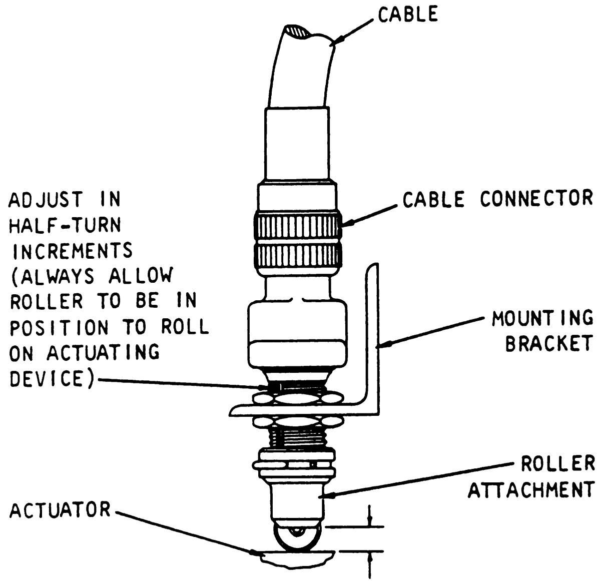
The two types of equipment-mounted interlock switches used in a gun system are the microswitch and the proximity switch.

MICROSWITCHES (SENSITIVE SWITCHES).—Microswitches (fig. 13-1), are of the standard type and are sealed plug-in units. The switches may be mounted either on a stationary or a moving component. The moving part of the switch can be a straight plunger, or the plunger may have a roller attachment. Plungers are used where actuator motion is linear; roller attachments are used where a camming surface acts on the switch (fig. 13-2).



83.90

Figure 13-1.—Adjustment measurement for plunger-actuated sensitive switch.


CABLE
CABLE CONNECTOR
ADJUST IN HALF-TURN INCREMENTS (ALWAYS ALLOW ROLLER TO BE IN POSITION TO ROLL ON ACTUATING DEVICE)
MOUNTING BRACKET
ROLLER ATTACHMENT
ACTUATOR

WITH SWITCH ACTUATED, MEASURE FROM NOSE OF ROLLER ATTACHMENT TO ACTUATOR SURFACE (0.250 IN.); WITH SWITCH DEACTUATED, MEASURE FROM NOSE OF ROLLER ATTACHMENT TO OUTER EDGE OF ROLLER (0.375 IN).

83.90

Figure 13-2.—Adjustment measurement for roller-actuated sensitive switch.

To adjust an equipment-mounted sensing switch, loosen the locknuts with a wrench. (The switch is secured to its bracket with a locknut on each side of a threaded hole.) Then position the switch assembly in the bracket in an actuated or deactuated position, in accordance with instructions listed in the particular equipment OP and/or the pocket-sized guides (OPs) that are issued on newer equipment (volume 8). In the case of a roller-attachment switch, adjust in half-turn increments. The final adjustment must ensure that the roller rides correctly on the actuating surface.

When checking switches, ensure that the required adjustments and the required position are correct. Depending upon your configuration and whether or not your logics require a 1 or 2 state, determines if your switch is actuated or deactuated during the adjustment.

PROXIMITY SWITCHES.—Proximity switches (fig. 13-3) are installed on components to sense component and ammunition positions. Each switch unit consists of a switch and a switch actuator (magnet). These switches are mounted on fixed components and the associated actuator is mounted on a moving component, the movement of which is sensed by the switch.

Proximity switches use either the Hall device or a reed switch as a sensor. The sensor and associated circuitry are encapsulated and sealed in a straight or 90° switch housing. A quick disconnect bayonet connector attaches the switch control cable to the switch. The cable supplies power to the switch and connects it electrically with an inverter buffer. The name proximity was derived from the fact that theses switches never touch its actuator.

When a proximity switch is actuated, its output voltage changes from about -1.2 volts dc to about +18 volts dc. If a switch actuator moves axially, the switch actuates when the air gap between the switch and its actuator is from 0.240 to 0.190 inch. If the switch actuator moves laterally, the switch actuates when the air gap is 0.093 inch and the actuator and switch axial centerlines mismatch about 0.078 (± 0.015) inch. These dimensions apply to a typically installed switch.

Solenoid-Mounted Interlock Switch Elements

Solenoid-mounted interlock switch elements indicate the status of the solenoid armature position. Each switch is actuated by an actuating leaf that is pressed against the switch button by an adjusting screw (fig. 13-4). The adjustments and precautions pertaining to these switches may vary from system to system, so you should refer to the applicable OP for precautions and procedures prior to attempting any maintenance.

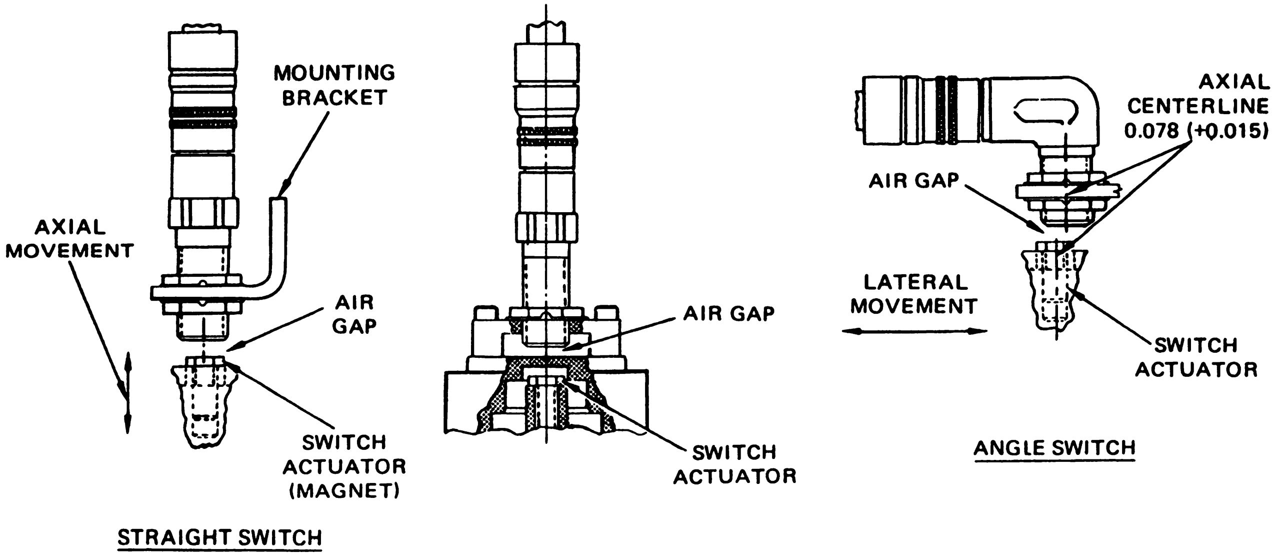


Figure 13-3.—Typical proximity switches.

ANSWERS TO QUESTIONS Q2 THROUGH Q4.

A2. In your system's OP.

A3. To prevent and detect failures.

A4. To detect grounds in the electrical system.

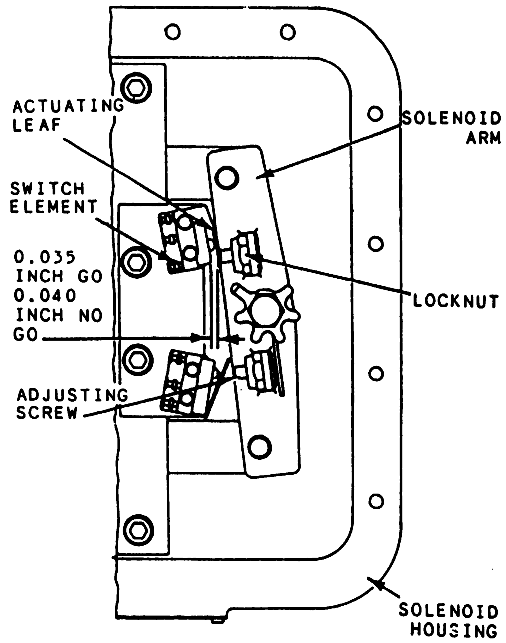


Figure 13-4.—Typical interlock switch elements in solenoid housing.

When items such as switches, relays, solenoids, and synchros malfunction, you should not attempt to repair them. Simply replace the faulty unit with a functional spare and adjust the new unit for proper system operation.

Q5. What is the function of an interlock switch?

Q6. What are the two types of interlock switches used in a gun system?

Q7. At what intervals should interlock switches be checked to see that they are functioning properly?

Cleaning Electrical Components, Contacts, and Switches

Since you were first handed a paintbrush aboard ship, you have been warned not to paint electrical equipment. If you were careless, you had to painstakingly clean it off. Dust and dirt on electrical and electronic equipment should be cleaned only by experienced personnel, and in accordance with applicable maintenance requirement cards (MRCs).

Though relatively easy to check, some switches are somewhat inaccessible, making cleaning and inspection a nuisance. After a visual inspection of the connections and the switches, a continuity test will indicate any malfunctions. Some switches are damaged during installation, particularly those with plastic housings. Proper care in installing or replacing plastic enclosed switches will eliminate this. Other switches depend on pressure to operate. These switches have adjustments so that they will operate at the correct time or pressure. In many cases if the adjustments are not accurate after cleaning, damage can result.

ELECTRONIC MAINTENANCE

Technical maintenance is normally limited to replacing unserviceable subassemblies or parts and aligning, testing, and adjusting the equipment. To perform effective maintenance, you must have a good working knowledge of basic principles of electronics. The only way to acquire this knowledge is by diligent study. You must be thoroughly familiar with the theory of operation of the equipment that must be serviced. A knowledge of the theory of operation can be acquired through study of equipment OPs.

Electronic control units, such as 5"/54 gun mounts, contain plug-in module boards and require only voltage tests and balance adjustments for maintenance. The MRCs for these systems explain the maintenance tests required for proper amplifier balance and power supply voltages. The operation of an electronic servo control unit is explained in chapter 6 of this text.

Ordnance control systems that use electric and electronic components not contained in module boards, i.e., (amplidyne power drives) made up of transformers, relays, capacitors, potentiometers, electron tubes, and solid state circuits, need a planned maintenance program to keep them in the proper state of readiness. The type of maintenance for such equipment varies with the type of equipment, but generally ensures that there is no evidence of overheating of amplifier components, no loose or broken parts (or tubes), no broken insulation no corrosion, fungus, dirt, or moisture on the amplifier, amplifier chassis, or related components.

When inspecting electronic and electrical components and evidence of fungus is found, comply with the applicable MRC for cleaning. When conducting maintenance on enclosed electronic equipment where desiccant bags are used, always install a new desiccant bag before replacing the equipment access cover. Moisture indicator strips should be used to monitor the usefulness of your desiccant.

ELECTRICAL AND ELECTRONIC FAILURES

Practically all electric shocks are due to human error rather than equipment failure. A death can almost always be attributed to a failure to follow safety instructions.

The safety devices provided for ordnance systems should be used as designed. The safety devices should be kept operative and in good order at all times. All safety devices should be inspected frequently. Inoperative safety devices should not be secured; they should be **repaired** or **replaced**. Covers of switches, circuit breakers, and other electrical equipment should be kept securely closed while powder and other explosives are exposed in the vicinity. Circuit breakers that have opened should not be closed until the cause of the overload has been established and repaired.

Unless specifically stated otherwise, all checking and maintenance procedures should be performed with the equipment shut down (all power secured). A person familiar with first aid procedures for electrical shock should always be available (never work alone).

Q8. Where can ready information on cleaning electrical components be found?

MECHANICAL MAINTENANCE

Mechanical maintenance is the routine inspecting and testing of a weapons system's mechanical adjustments. When a routine maintenance check reveals that a particular unit or assembly is out of adjustment, or when repairs are made as a result of wear or casualty to equipment, readjustment procedures must be performed. When mechanical adjustments or readjustments are performed, all electrical switch adjustments must be rechecked and/or adjusted as necessary. When both mechanical adjustments and switch adjustments are needed, you should make the mechanical adjustment first.

The purpose of mechanical maintenance is to ensure that all elements of an ordnance system are in proper alignment with respect to a centerline reference point. On some ordnance systems, special tools and accessories are provided for mechanical testing and adjustments.

TORQUE TESTING

On the 5"/54 gun system, a hoist chain tension tool is used to test and adjust the lower hoist chain for proper tension. Figure 13-5 illustrates how the tension tool is connected to the hoist lower sprocket assembly for testing. Before inspecting and testing the lower hoist chain tension adjustment mechanisms, be sure that the lower hoist and loader motors are **off** and that the hydraulic pressure in both the lower hoist and loader accumulator system have been double- or even triple-dumped to tank. Residual pressure has been known to actuate hydraulically operated equipment.

Connect the chain tension tool to the lower sprocket adjustment arm. By means of this tool, apply 50 pound-feet of torque to the arm in the direction that will increase the chain tension. As torque is applied, move the bumper seat over against the adjustment arm and take up the slack by turning the bumper arm guide against the

ANSWERS TO QUESTIONS Q5 THROUGH Q7.

A5. To indicate the position of equipment and solenoids.

A6. Mircoswitches and proximity switches.

A7. Monthly and quarterly.

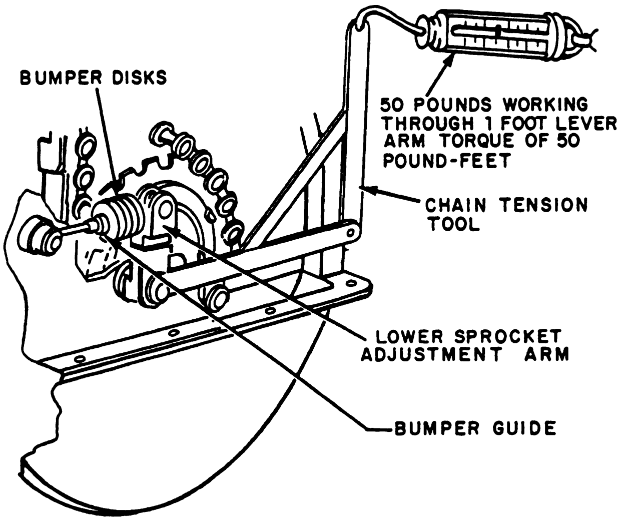

BUMPER DISKS
50 POUNDS WORKING THROUGH 1 FOOT LEVER ARM TORQUE OF 50 POUND-FEET
CHAIN TENSION TOOL
LOWER SPROCKET ADJUSTMENT ARM
BUMPER GUIDE

Figure 13-5.—Lower hoist chain tension adjustment mechanism.

bumper discs. Ensure they are held snugly together between the guide and seat. Lock the adjustment by turning the locknut against the bumper guide.

MECHANICAL ADJUSTMENTS

There are numerous mechanical adjustments to be checked. We could devote an entire book to making these adjustments. It is recommended that you consult your systems publications for detailed adjustment procedures.

Q9. When making switch and mechanical adjustments, which should be made first?

INSPECTION DURING MAINTENANCE

When checking or making mechanical adjustments, inspect the lubricants used on sliding surfaces, linkages, plungers, and shafts. Inspect moving parts and lubricants to determine whether changes in lubricants are required.

When any previously observed conditions indicate the need for replacement or renewal of lubricants, the necessary corrective action should be taken.

SAFETY WIRING

Screws, bolts, electrical and mechanical connectors, and other devices are safety wired as additional security against the effects of vibration. The safety wire used is corrosion resistant steel (which complies with MS 20995 unless otherwise specified).

The common range of safety wire is from 0.020 inch to 0.091 inch in diameter. The largest diameter wire that the drilled holes in the fastener will accommodate, should be used. The double-twist method safety wiring shown in figures 13-6 and 13-7 is recommended for use on all ordnance equipment.

The following are some simple guidelines to follow when you are using safety wire to complete a repair:

1. All fasteners to be safety wired must be torqued to the recommended values before proceeding with the safety wiring operation.
2. New safety wire should be used on each application. If, in the event that you make a mistake, remove the damaged safety wire and start over.

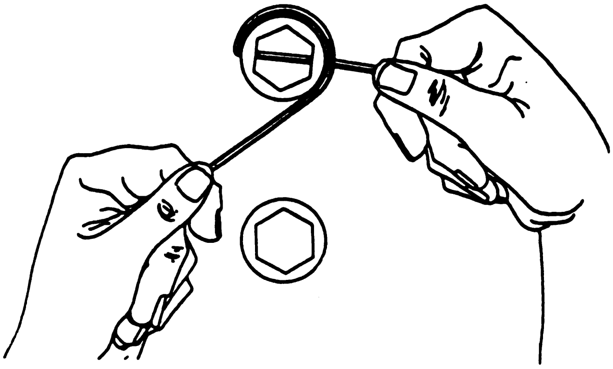
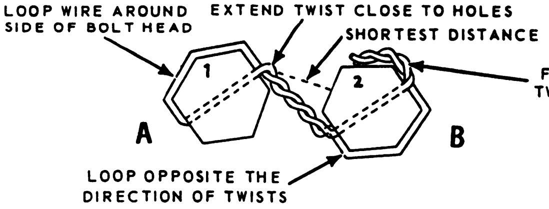


Figure 13-6.—Safety wiring, started.


LOOP WIRE AROUND SIDE OF BOLT HEAD
EXTEND TWIST CLOSE TO HOLES
SHORTEST DISTANCE
FOUR TWISTS
1
2
A
B
LOOP OPPOSITE THE DIRECTION OF TWISTS

12.245

Figure 13-7.—Safety wiring, completed.

3. Safety wire no more than three fasteners in series.

4. The safety wire should always be installed and twisted so that the loop around the head stays down and does not tend to come up over the fastener head, causing a slack loop. This is accomplished by twisting the wire so that the loop around the head passes through the hole (fig. 13-6). An exception to the rule occurs when a third fastener is in the series. Due to the direction of twist, the loop will pass over the wire passing through the fastener hole on the entrance side.

5. Wire-twister pliers are three-way pliers which hold, twist, and cut. Keep the two wires side by side, not crossed, when grasping the wires between the pliers jaws. Squeeze the pliers to clamp the wires and then the thumb can bring the locking sleeve into the lock position.

6. If wire-twister pliers are not available, or working space is limited, use hands to twist the wires, keeping the wires parted at a 60° angle. Never use regular pliers for twisting safety wire because they will damage the wire.

7. All safety wire should be tight and free of kinks after installation, but not under such tension that normal handling and vibration will break the wire.

8. Make sure the installed safety wire will not interfere with moving components.

9. Ensure all wire scraps are removed from the work area since they can cause equipment damage.

Under conditions of severe vibration, the coupling nut of the AN connector may vibrate loose; and with sufficient vibration, the connector could come apart. When this occurs, the circuit carried by the cable will open. The proper protective measure to prevent this occurrence is a safety wiring attachment as shown in figure 13-8. Remember, any time a safety wire is not replaced, a failure may result. The safety wire should be as short as possible and must be installed in such a manner that the pull on the wire is in the direction that tightens the nut on the plug.

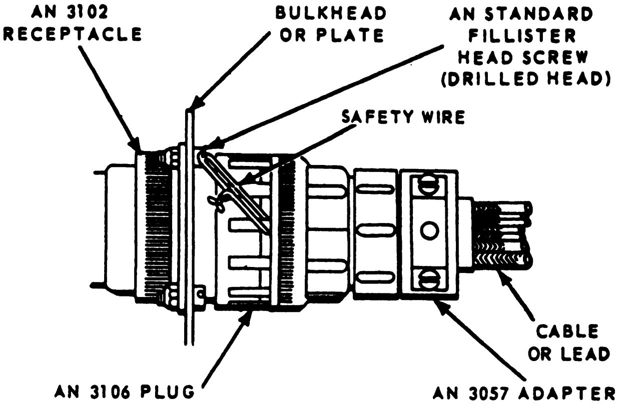


Figure 13-8.—Safety wiring for plug AN connectors.

Q10. When making a safety wire wrap by hand, what is the proper angle of the wire wrap?

TESTING HANDLING EQUIPMENT

Ammunition handling equipment should be tested at the time of its installation aboard ship. Subsequent testing should be made to detect any deterioration that has occurred during its use. For this reason, periodic testing and inspection of weapon and explosive ordnance handling equipment is needed to indicate the equipment's ability to carry its rated load. The testing of shipboard handling gear is accomplished in accordance with NAVSEASYSCOM instructions and OD 44941.

MECHANICAL SAFETY

Each MRC lists the applicable safety precautions to be observed before making any mechanical adjustments. In most cases the instructions include:

1. Ensuring the electrical power is deenergized and properly tagged.

ANSWERS TO QUESTIONS Q8 AND Q9.

A8. On the applicable MRC.

A9. Mechanical.

2. Ensuring the accumulator pressures are dumped to tank.

3. Ensuring the safety links and securing pins are connected to prevent the accidental movement of equipment.

4. Ensuring phone communications are available to all key personnel prior to any mount or equipment movement.

Q11. Information on the testing of handling equipment may be found in which OD?

HYDRAULIC SYSTEM MAINTENANCE

Satisfactory operation of hydraulic power drive systems is sustained by proper maintenance. Maintenance of hydraulic systems is to prevent hydraulic fluids from becoming contaminated. Reports received from fleet units indicate that contaminated hydraulic fluids have caused extensive damage to shipboard hydraulic systems. Cylinder barrels, valves, valve plates, pistons, bushings, and bearings are some of the units that have been damaged by contaminated hydraulic fluids.

PREVENTING CONTAMINATION

When hydraulic equipment is overhauled or repaired, several precautions should be followed to prevent contamination of hydraulic fluids.

1. Parts should be inspected for excessive wear and replaced when necessary.
2. All openings into hydraulic systems should be kept closed to keep foreign materials out.
3. When the hydraulic units are not being worked on, they should be covered with a clean cover.
4. Clean or replace the filter elements.
5. Do not weld, braze, or solder tubing after assembly of the equipment unless absolutely necessary. Proper cleaning of installed hardware is difficult.
6. Before reassembling, remove all dirt, sludge, water, and rust.

FILTERING

Before filling a hydraulic system or replacing fluid after flushing, the fluid to be replaced in the system shall first be strained through a No. 200 (74 micron) sieve or finer No. 400 (37 micron) sieve to remove the coarser particles that may be present. The No. 400 sieve is preferred. In addition, it is recommended that the fluid be pumped through a portable filter, especially for hydraulic equipment containing controls with close tolerance parts. Care should be taken to use the proper filter element to prevent the removal of additives.

When micronic filters are specified for the equipment, a 10-micron filter element may be used provided it does not remove additives.

CONTAMINATION CHECKS

Whenever it is suspected that a hydraulic system has become excessively contaminated, or the system has been operated at temperatures in excess of the specified maximum, a check of the system should be made. The filters in most hydraulic systems are designed to remove most foreign particles that are visible to the naked eye. However, hydraulic fluid which **appears clean** to the eye may be contaminated beyond use.

Liquid samples should be taken in accordance with the instructions provided in applicable technical publications for the particular system.

In hydraulic systems which use accumulators, serious injury may result if the high accumulator pressures are not dumped to tank prior to taking samples. In such systems, ensure that all accumulator pressures are released by securing all accumulator motors and by pulling the handles of the system's manual unloading valves, thus releasing the accumulator pressures.

OPERATION UNDER ENVIRONMENTAL CHANGES

Naval ordnance systems are usually designed to operate over a certain ambient temperature range; therefore, the material used in hydraulic systems must be selected to ensure reliable and efficient operation over this range. For example, shipboard ordnance normally is expected to operate satisfactorily over the temperature range -20° to 190°F.

Sluggish operation or failure of equipment to operate may be expected under cold weather conditions if preparations for entering such areas have not been adequate. Hydraulic systems should be prepared for cold weather operation by using appropriate low temperature hydraulic fluids. These fluids should be used in those cases where the unique properties would be advantages. Hydraulic fluid, MIL-F-17111, should not exceed 190°F. In cold weather, exercising of the system for 15 minutes prior to service operation will generally result in improved operation. *Lubrication of Ordnance Equipment*, OD 3000, lists the properties of power transmission hydraulic fluids used for different temperature ranges. If hydraulic fluid must be changed for operation under extreme climatic conditions, low temperature fluids, such as MIL-H-5606 (-65° to 275°F), may be used.

HYDRAULIC EQUIPMENT SAFETY

If a leak is discovered in one of the hydraulic pipe connections and repair work requires removal of a section of piping or opening a line, the piping or coupling should not be removed without first draining the associated hydraulic system and observing the following safety rules:

1. Shut down the hydraulic system before undertaking any repairs.
2. Release all fluid pressure before disconnecting any pressure line.
3. Release all gaseous nitrogen pressure before disconnecting the line to the accumulator. Ensure the system pressure is zero by use of a pressure gage only.
4. Open all doors to a ship's compartment housing pneumatic accumulator systems before venting equipment charged with air or nitrogen to the atmosphere.
5. Do not allow hydraulic fluids to exceed their working temperature range. Danger of combustion exists when an electric spark is generated in the vicinity of overhead hydraulic fluid.
6. Change into dry clothing immediately if clothing becomes drenched with hydraulic fluid. When in prolonged contact with the skin, hydraulic fluid can injure health.

A mixture of hydraulic fluid and oxygen will explode, resulting in serious or fatal injury to personnel and causing extensive damage to the equipment being serviced. Since nitrogen and oxygen are both furnished in metal cylinders, exercise extreme caution so you will not choose the wrong cylinder. Oxygen always comes in a green cylinder; nitrogen always comes in a gray cylinder with one or two black bands near the top.

STORAGE OF FLUIDS AND LUBRICANTS

The effects of overheating, insufficient ventilation, and proximity to dangerous materials must be considered when storing hydraulic fluids and lubricants. Good housekeeping in storage areas should be stressed at all times.

There are no standard tests to determine the storage life of fluids and lubricants. The best available information is derived from practical experience and long-time observation. It is not good practice to allow fluids to be stored indefinitely since accuracy and usefulness of storage life estimates is of doubtful value and is less reliable than periodic examinations of the fluids. Materials stored for service use should be examined semiannually. It is good practice to keep an accurate record of lubricants and fluids used, and use old stock first.

Q12. Under normal operations, you can expect your system to operate satisfactorily within what temperature range?

INSPECTION OF STORAGE AREAS

Before containers are stored, inspect them for corrosion, leakage, and complete closure of all plugs, caps, and covers. Remove all corrosion and repaint the affected containers.

FLAMMABLE STORAGE AREAS

All units of the Navy have special oil and grease lockers that are provided for the storage

ANSWERS TO QUESTIONS Q10 AND Q11.

A10. 60°.

A11. OD 44941.

of flammable materials used with ordnance equipment. The inspection, maintenance, and upkeep of these spaces may be the responsibility of ordnance personnel.

A temperature range of 40° to 80°F is most desirable for the storage of flammable materials. Lubricants and fluids should be segregated from all types of explosives and other dangerous materials.

UNSCHEDULED MAINTENANCE PROCEDURES

Unscheduled maintenance procedures are actions performed for special ordnance operations, such as prefiring and postfiring tests, battery alignment procedures, system performance tests, and other maintenance actions performed after a major overhaul or repair. System MRCs are used for most of the unscheduled maintenance procedures.

Since a gun mount is only a part of a weapons system, it must function properly to ensure maximum system performance. Unscheduled prefiring maintenance for a gun mount and its ammunition loading equipment checks the mechanical, electronic, electric, and hydraulic components. Other subsystems of a weapons system (i.e., gun/missile radar, computers, sonar equipment) must have unscheduled maintenance tests conducted on them to determine their readiness prior to firing. When all subsystems report satisfactory completion of a required maintenance action, the weapons system should then be ready to perform its mission.

PREFIRING MAINTENANCE CHECKS

Prefiring checks consist of inspecting recoil and counter- recoil systems and testing firing cutouts and limit-stop mechanisms. They also consist of firing primers from both the normal and emergency firing sources and verifying that the safety links and securing pins are disengaged. Preoperational checks and tests should also be conducted on all ordnance units to ensure their operability in all modes of control.

Firing Cutout Systems

Several different types of firing cutout systems are used to protect areas of a ship against accidental firing. One method, called the automatic pointing cutout system, prevents the ordnance units from pointing toward the structure of a ship. The areas of a ship's structure that can be endangered through direct physical interference from the ordnance unit are called nonpointing zones.

Another method, called the firing stop mechanism (firing interrupter), cuts out the firing circuits whenever the line-of-fire of the ordnance unit nears the ship's structure. The firing cutout system prevents firing when the ordnance unit is near or pointed into a preset danger sector. The pointing cutout system prevents the ordnance system from training or elevating into a danger zone.

The maintenance methods of these systems differ, but basically the prefiring maintenance test procedures accomplish a ready-to-fire status for a unit of ordnance equipment. Firing zone parameters (assigned limits) are established by NAVSEASYSCOM for each unit of a weapons system at the time of installation aboard ship and at such other times when the ship's structure is altered near an ordnance unit. The parameters—train and elevation firing zone limits—are recorded in an installation OD for each ship and should be compared when prefiring checks are conducted. A test lamp, connected by a lead to the terminal of a firing pin mechanism and the other lead grounded, is used on systems where there is no firing zone clear or danger lights installed to determine the conditions of the firing zone cutout system.

Either the test lamp or the firing light indicates the condition of a firing cutout system (ON—in a clear sector and OFF—in a danger sector), and the parameters (train and elevation position readings) determine the safe/danger condition by the light indications.

Most pointing cutout systems use a firing zone CLEAR or firing zone NOT-CLEAR light to indicate the status of the firing circuit. When conducting prefire checks for this type of system, a more elaborate check system is used to establish the physical positions of the ordnance units in relation to their firing cutout parameters.

Most ships use a three-zone, nonpointing cutout system where each zone has its own set of parameters. Each set of parameters must be checked and recorded every time prefiring checks are conducted. Since the automatic pointing cutout system prevents the ordnance unit from entering a nonfiring zone, the physical position of the ordnance unit must be checked against those recorded in the system installation OD.

When approaching a nonfiring zone, the automatic limit-stop mechanisms are mechanical, electrical, and hydraulic systems, which must be properly maintained through testing and adjusting prior to prefiring checks. The operation of an automatic pointing cutout system is explained in chapter 6 of this manual.

The firing zone CLEAR and firing zone NOT-CLEAR lights are used as guides when conducting prefiring checks and are used to indicate the on/off condition of a firing circuit. Both train and elevation position readings are taken whenever the status of lights change. A reading is taken when the firing zone clear light goes out and another reading when the firing zone not-clear comes on. This method is used to double check the condition of the firing cutout system by indicating the safe/unsafe condition at approximately the same bearing. In this type of system, two circuits are used to control the firing cutout system, and both circuits must function within the present parameter limitations. An example of how firing cutout indicating lights help during a maintenance action would be when an ordnance unit is coming out of a nonfiring zone condition into a firing zone condition; both lights must indicate a condition not within the preset parameters, an indication of a problem for the zone being checked could be determined and corrected during a scheduled maintenance action and before a prefiring unscheduled maintenance action is conducted.

After completion of a firing cutout system check, the firing circuits are then tested by firing test primers at least once from each firing position. On systems using a combination primer, the mechanical firing mechanisms are also tested. After primers are fired, the spent primers should be inspected to ensure indentations made by the firing pins are not offset from the center of the primer's base more than the allowable limits listed on a system's MR prefiring card.

Q13. What activity establishes fire zone parameters?

Limit-Stop System Testing

A limit-stop system provides an ordnance unit with the ability to arrest its movement both in train and elevation at predetermined points before the extreme positive stop, or parameter limits, are reached. A limit-stop system does not interfere with normal operation of a system that is within its normal operating limits. Limit-stop mechanisms function in all methods of power operation. Limit-stop action depends upon the velocity of an ordnance unit at the instant the limit-stop mechanism takes control. This arrangement permits the ordnance unit to be stopped smoothly at the same limits of travel regardless of the velocity as the limit-stop position is approached.

Ordnance systems that use an automatic nonpointing system use a limit-stop system in a different way, which prevents the ordnance unit from training or pointing into a danger zone. The limit-stop mechanism for these systems actuate an override device which causes the ordnance unit to elevate above a danger zone and stops train movement into a danger zone before the present elevation limit is reached. Normal operation resumes when the ordnance unit is trained past or elevated over the affected danger zone. Maintenance of a limit-stop system consists of several different electrical, mechanical, and hydraulic adjustments, which permit the limit-stop system to operate at about 2° away from a positive (hard) stop position or a preset value from a nonpointing zone parameter setting.

Recoil and Counterrecoil Systems

Maintenance of these systems, usually on a monthly basis, requires that the gun(s) be run out of battery and counterrecoil components be conducted for signs of scoring, galling, and any deformations. After lubrication and cleaning maintenance are performed, the guns are run to the in-battery position and the air pressure in the counterrecoil system is charged to its operation levels. Whenever a counterrecoil system is charged, always use air-never oxygen. Counterrecoil systems are also inspected to ensure

ANSWER TO QUESTION Q12.

A12. $-20°$F to 190°F.

that the protrusion of the differential piston is not more than 2 inches beyond the packing gland face.

Q14. A limit-stop system is designed to operate how many degrees from the hard stop?

GUN BARREL MAINTENANCE

The working surfaces of the gun barrel are the rifling and the forward end of the chamber. As time passes and rounds are fired, these surfaces will deteriorate and require maintenance to ensure their continued usefulness. The main causes of deterioration are erosion, corrosion, dirt, copper fouling, and constriction.

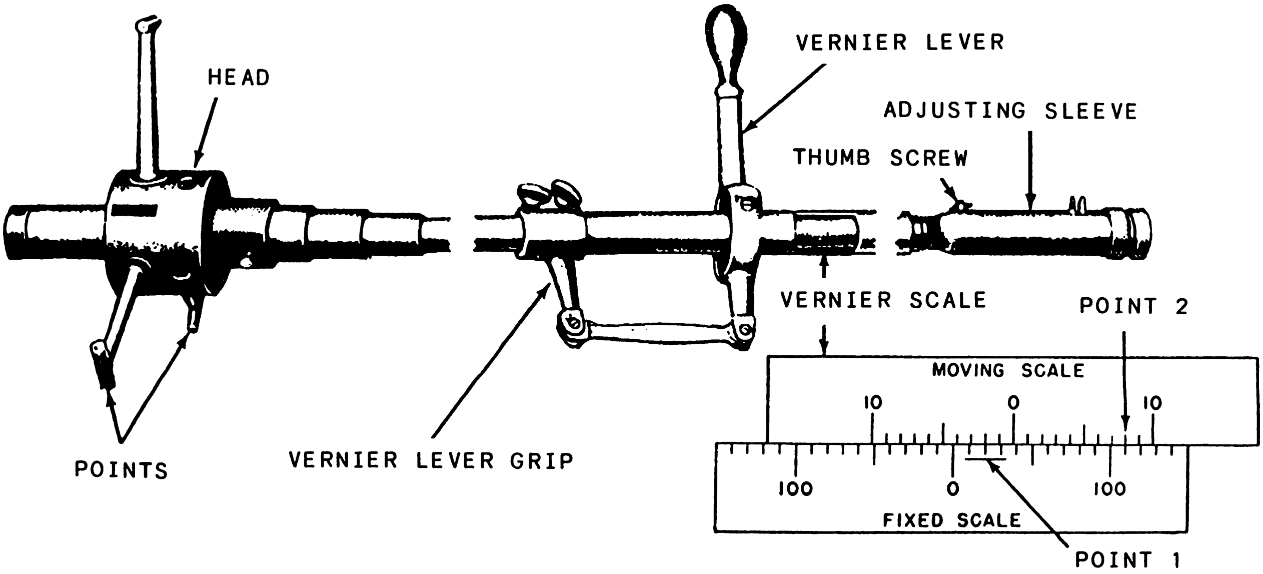
Gun Wear

Erosion is the deterioration and wearing away of the bore surface caused by firing projectiles through it. Two measures of gun wear are commonly in use: bore enlargement at the origin and erosion gage readings. These are separate, independent measures of gun wear, but are related to each other. Current NAVSEAINST 8300.1A and OP 1549 explain the conditions for requesting regunning when either the bore enlargement at the origin or erosion gage readings reach the condemning point (80 percent expended), or the barrel has reached the specified fatigue life. There are two special tools (test equipment) used to measure bore erosion: the star gauge, and the MK 9 Mod 0 projectile seating distance gage (PSDG) for use in the 5"/54 guns.

Star Gauge

The star gauge (fig. 13-9) consists of a head mounted on a long tube, with metal points 120° apart extending radially from it. These three points form a Y and press against the bore of the gun. Points of suitable length are provided for each caliber of gun to be measured. The bases of the points are spring-loaded to bear against a tapered expanding plunger; as the plunger (operated by the vernier lever) moves lengthwise, the points are cammed outward or inward. Measurements are read from the vernier scale. The results of star gauging measurements are reported on NAVSEA Form 3000/2 (explained in chapter 12).

Star gauging is performed by trained personnel or the ordnance field in tender, or shore-based repair facilities. The object is to measure the amount of erosion along the bore (and especially its origin) so that the corresponding predicted loss in I.V. (initial velocity) can be included in the fire control solution. Tables, charts, graphs, and



110.55

Figure 13-9.—Star gauge.

equations are provided to convert erosion losses into usable I.V. information.

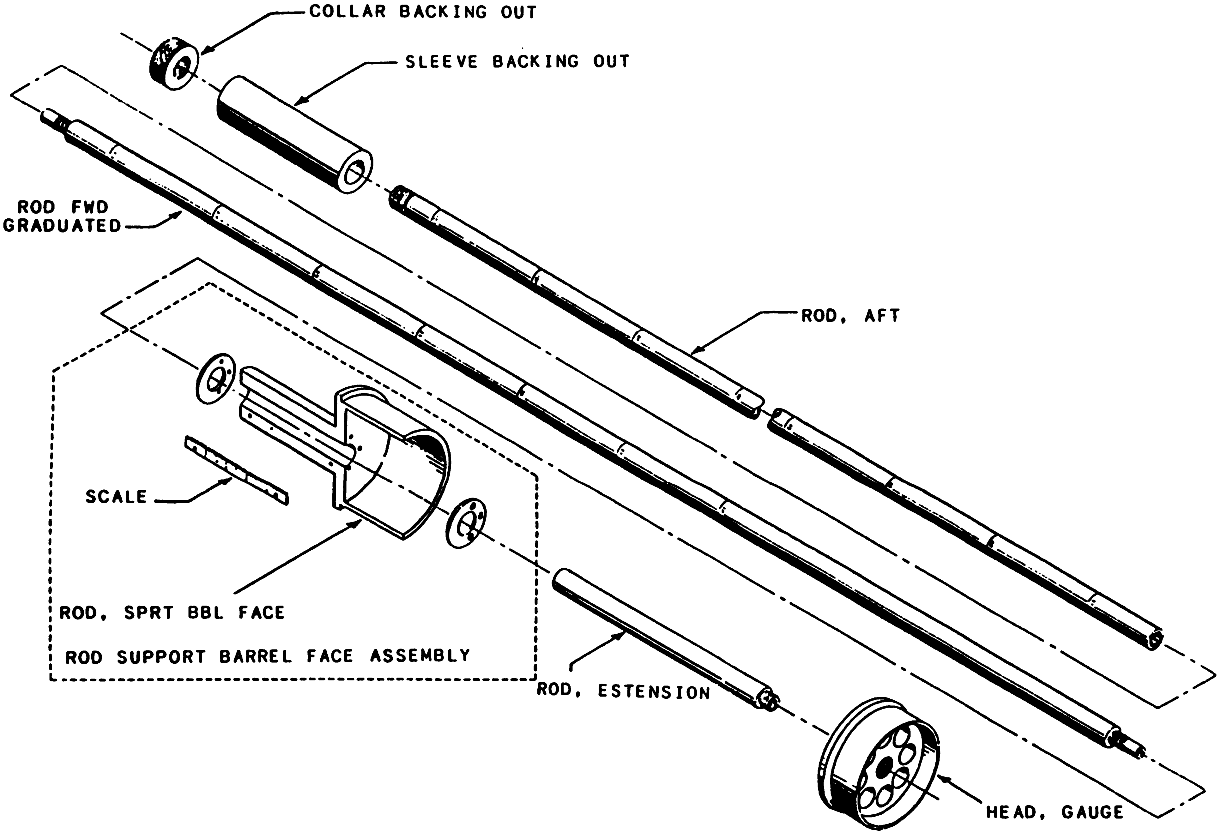
Mk 9 Mod 0 Projectile Seating Distance Gage (PSDG)

The Mk 9 Mod 0 projectile seating distance gage (fig. 13-10) was developed to replace the 5" Mk 2 bore erosion gage for estimating velocity losses and percent-expended conditions in all 5"/54 gun barrels.

The PSDG is similar in construction to the old Mk 2 bore erosion gage. The major difference is that the PSDG measures seating location of the projectile, rather than the wear near the origin of the bore. For instructions and use of the Mk 9 Mod 0 PSDG, see OP 1549, NAVSEAINST 8300.1, and your MRCs.

MAINTENANCE PUBLICATIONS AND NOTICES

System OPs are ordnance publications that describe the physical and functional characteristics of an ordnance system or unit and provide



53.365

Figure 13-10.—Mk 9 Mod 0 PSD gage.

ANSWERS TO QUESTIONS Q13 AND Q14.

A13. NAVSEASYSCOM.

A14. 2°.

maintenance and operating procedures for personnel assigned to the system. Most systems OPs are a series of volumes for each major assembly and an illustrated parts breakdown (IPB) publication.

ILLUSTRATED PARTS BREAKDOWN (IPB)

A system IPB describes and illustrates the parts for a gun mount and is intended for use during corrective maintenance of the subject equipment. An IPB is broken down into sections that identify parts for maintaining the equipment, for illustrating assembly relationships, and for requesting repair parts.

SWS TECHNICAL BULLETINS

Surface warfare systems technical bulletins are published about conventional ordnance systems when a maintenance problem caused by a mechanical failure creates concern over a part that might cause damage to personnel and equipment. SWS bulletins are published by NAVSEA-SYSCOM and explain the purpose, background, and actions that must be taken to either reduce or solve a maintenance problem. They also explain the inspection procedures that must be taken to ensure both safety and reliability of a specific part that may have caused concern. This will ensure that corrective steps are taken in time to prevent a possible casualty. Some of the actions taken from these bulletins are usually incorporated into the system OPs in the form of changes. The related MRCs are revised, or an ORDALT may be issued.

NAVSHIPS PUBLICATIONS

Some ship weapons systems use what was formerly NAVSHIPS equipment for magazine firefighting systems (sprinkling systems), and magazine security alarm systems. For maintenance testing, and operating instructions of this equipment, NAVSHIPS publications will be changed to NAVSEA publications when they are updated.

Q15. What two inspections tools are used to determine barrel life?

MAINTENANCE PROGRAMS

A maintenance program will keep a weapons systems in proper working order as long as a good maintenance crew performs all assigned maintenance actions. To follow the 3-M Systems' program by keeping maintenance actions does not constitute a reliable weapons system. To put a mark in a weekly schedule that indicates a maintenance action when the maintenance was not performed provides for a weak maintenance system.

A good maintenance program can be determined by the down time of the equipment, and material inspections.

BOARD OF INSPECTION AND SURVEY

The Board of Inspection and Survey conducts material inspections of all newly built or converted ships and service craft, and such other trials and ship inspections as may be directed by the Chief of Naval Operations. There is a statutory requirement that the board inspect all ships every 3 years. Whenever practicable, such inspections are sufficiently in advance of a ship's regular overhaul to permit accomplishment of work resulting from the board's recommendations. Present policy calls for this inspection to be conducted 4 to 6 months in advance of the schedule's overhaul period.

Prior to inspection, the ship's commanding officer must submit to the board a list of all repairs and alterations deemed necessary. Virtually everything on board must be opened up prior to the arrival on board of the inspection team—3M Systems' records as well as all logs and other records. (The material and ordnance histories, and the CSMP ledger must be made available for the inspection party's examination if these are still being maintained.) The material records will be given a very careful analysis. They must be accurate and up to date.

Upon completion of the inspection, the board will report the general condition of the ship and suitability for further naval service, together with a list of the repairs, alterations, and design changes which, in its opinion, should be made. These reports are made to CNO with copies to the fleet and type commanders. The board's recommendations ordinarily become the basis for work to be done by the shipyard, tender, or ship's force.

INSURV INSPECTIONS

INSURV material inspections are conducted in accordance with statutory requirements of Congress that specify the material inspection of a U. S. Navy ship (1) upon the ship's return from a foreign station, (2) at least every 3 years (if practicable), (3) when fitness of the ship for further service is in doubt, and (4) when the ship has been declared unfit and stricken from the Naval Vessel Register.

The INSURV board inspects all parts of the ship including storerooms, magazines, operating spaces, voids, cofferdams, chain lockers, and tanks. The spaces will be opened for inspection in accordance with detailed instructions on the condition sheets. Personnel must be available to open locked spaces immediately upon arrival of the inspection parties. The personnel responsible for a space and the operation of the equipment therein must be present in the space to assist the inspection party by answering questions and operating equipment.

The operational aspects of all equipment and material will be examined during conduct of the INSURV material inspection with the exception of equipment opened or dismantled for a more detailed inspection. Detailed instructions for the preparation of equipment for the inspection in each department are included with the condition sheets for the department.

The general inspection criteria for shipboard weapons are as follows:

1. Check the operation and arrangement of all equipment to ensure that the installation will properly support the ship's mission and tasks.
2. Determine the status of spaces assigned to the weapons department with regard to the size, ventilation, air-conditioning, lighting, etc.
3. Check all safety items pertaining to safety of personnel and material.
4. Check adequacy of maintenance and repair of weapons equipment including maintenance records and implementation of PMS.

All weapons spaces, except living spaces, will be inspected by the weapons inspector. Emphasis will be placed on proper demonstration of equipment and systems. The test program outlined in the applicable OD will be used as a guide in the conduct of the inspection. Those ships for which a test program has not been issued will be required to demonstrate all weapons systems. This includes inspection/demonstration of all of the following:

1. Target designation systems
2. Mount/launcher operation in all modes
3. Fire control systems including fire control radars
4. Ammunition stowage spaces
5. Weapons handling systems including both strike up and strike down facilities
6. Magazine sprinkling systems
7. Flooding and high temperature alarm systems

SUMMARY

Safety cannot be over emphasized. Use the publications that are at your disposal to maintain your equipment in peak operating conditions. COMNAVSEASYSCOM, Naval Ordnance Station, Louisville, or any other facility responsible for the development of technical publications cannot give you the common sense necessary to operate and maintain your equipment safely and efficiently. This has to come from many years of on the job training, practical experience, and the desire to excel as a Gunner's Mate.

Use the publications and procedures listed within this chapter to develop yourself and those you are responsible to train. Make it a point to familiarize yourself with even the most minor of publications. This will make the difference when you must react to a crisis or deal with an unusual situation.

REFERENCES

Gunner's Mate G 1 & C, NAVEDTRA 10186-D2, Naval Education and Training Program Management Support Activity (NETPMSA), Pensacola, Fla., 1989.

ANSWER TO QUESTION Q15.

A15. Star gauge and projectile seating distance gage.

INDEX

A

- Administrative duties, 12-1 to 12-20
  - forms, 12-3
  - periodic inspections—types and requirements, 12-19 to 12-20
    - administrative inspection, 12-20
    - material inspections, 12-19
    - operational readiness inspection (ORI), 12-19
  - physical security of classified material, 12-16 to 12-19
    - care during working hours, 12-16 to 12-17
    - care of working spaces, 12-16
    - combinations and keys, 12-17 to 12-18
    - reproduction of classified information, 12-18 to 12-19
      - destruction of classified material, 12-19
      - printing, duplicating, and reproduction of classified material, 12-18 to 12-19
    - responsibilities of custodians, 12-16
    - securing classified material, 12-17
    - storage of classified material, 12-17
  - reports, 12-1 to 12-3
    - types of reports, 12-1 to 12-3
      - ammunition reports, 12-3
      - gun wear/star gauge reports, 12-1 to 12-3
  - requisitioning ammunition, 12-8 to 12-12
    - requisitioning ammunition by naval message, 12-10 to 12-12
    - requisitioning ammunition with DD Form 1348, 12-8 to 12-10
    - turn-in of ammunition, 12-12
  - shipboard gunnery logs and records, 12-3 to 12-8
    - ammunition ledger, 12-4 to 12-6
    - coordinated shipboard allowance list (COSAL), 12-6
    - logs, 12-3 to 12-4

- Administrative duties—Continued
  - shipboard gunnery logs and records—Continued
    - logs—Continued
      - ballistics logs, 12-4
      - magazines temperature log, 12-4
      - small arms log, 12-4
    - ordnance alteration (ORDALT), 12-7
    - ship's armament inventory list (SAIL), 12-7 to 12-8
  - 3-M Systems, 12-12 to 12-16
    - intermediate maintenance activity (IMA); intermediate maintenance management system (IMMS), 12-15 to 12-16
    - maintenance data system (MDS), 12-15
    - planned maintenance system (PMS), 12-12 to 12-15
- Advanced?, who will be, 1-11
- Advancement, 1-10 to 1-14
- Advancement Handbook for Petty Officers, The, 1-11 to 1-12
- Advancement opportunities for senior petty officers, 1-12 to 1-14
- Alignment, definition of, 8-1 to 8-4
- Alignment equipment, 8-4 to 8-12
- Alignment procedures, 8-12 to 8-14
- Alignment responsibilities, 8-4
- Alignment, theory of, 8-1 to 8-14
- Ammunition allowance, shipfill, 11-2
- Ammunition allowances, training, 11-2 to 11-3
- Ammunition, general regulations for handling, 11-3 to 11-8
- Ammunition handling and stowage, 11-1 to 11-22
  - allowance lists, 11-1 to 11-3
    - shipfill ammunition allowances, 11-2
    - training ammunition allowances, 11-2 to 11-3

Ammunition handling and stowage—Continued
  - ammunition stowage aboard ship, 11-8 to 11-11
    - ammunition passing scuttles, 11-10 to 11-11
    - designation of magazines, 11-9 to 11-10
      - multipurpose magazines, 11-9 11-10
      - single-purpose magazine, 11-9
    - identification of ammunition stowage spaces (far side), 11-10
    - magazines fittings and equipment, 11-10
    - ready-service stowage, 11-11
    - sprinkling systems, 11-10
    - Types of magazines, 11-9
      - chemical magazines, 11-9
      - lockers, 11-9
      - missile magazines, 11-9
      - primary magazines, 11-9
      - ready-service magazines, 11-9
    - work limitations and security of magazines, 11-11
  - general regulations for handling ammunition, 11-3 to 11-8
    - exceptions, 11-3
    - general instructions, 11-4 to 11-5
    - inspection before accepting, 11-7
    - loading/offloading plan, 11-6 to 11-7
    - methods of handling, 11-7 to 11-8
      - hazards of electromagnetic radiation to ordnance (HERO), 11-8
      - precautions to be observed, 11-7
      - special precautions for bomb-type ammunition, 11-8
    - operation at night, 11-7
    - responsibility for proper handling, 11-3 to 11-4
    - supervision of personnel and equipment, 11-5 to 11-6
      - equipment requirements, 11-5 to 11-6
      - personnel requirements, 11-5
  - handling techniques, 11-15
  - regulations for stowage of ammunition, 11-11 to 11-15
    - ammunition, miscellaneous, 11-14
    - chemical ammunition, 11-13
    - detonators, fuzes, and boosters, 11-12

Ammunition handling and stowage—Continued
  - regulations for stowage of ammunition—Continued
    - grenades, 11-13
    - igniters, 11-13
    - permissible stowage of ammunition and explosives, 11-14
    - rocket-type ammunition, 11-13 to 11-14
      - air-launched rockets, 11-13
      - surface-launched rockets, 11-14
      - temperature control, 11-14
    - smokeless power, 11-12
    - stowage of equipment in magazines, 11-14
    - surface-launched missiles, 11-14
  - return of ships ammunition to ammunition activities, 11-15 to 11-22
    - handling equipment, 11-16 to 11-18
      - ammunition slides and chutes, 11-16 to 11-17
      - cargo nets, 11-16
      - mats, 11-17 to 11-18
      - pallet adapters, 11-18
      - skip box, 11-18
    - normal return of ammunition, 11-15 to 11-16
      - applicable publications, 11-16
      - gun ammunition, 11-15 to 11-16
      - procedure for returning ammunition, 11-16
      - special return of ammunition, 11-16
    - safety precautions for industrial handling equipment, 11-20 to 11-22
    - special handling regulations for bulk explosives and gun-type ammunition, 11-18 to 11-20
      - explosive components, 11-20
      - power tanks and cartridge tanks, 11-19 to 11-20
      - projectiles, 11-18 to 11-19
      - small arms, 11-20

Ammunition passing scuttles, 11-10 to 11-11
Ammunition, requisitioning, 12-8 to 12-12
Ammunition, regulations for stowage of, 11-11 to 11-15
Ammunition, rocket-type, 11-13 to 11-14
Ammunition stowage aboard ship, 11-8 to 11-11
Ammunition ledger, 12-4 to 12-6

- Amplidyne control equipment, 4-1 to 4-21
  - control circuits, gun, 4-3 to 4-17
    - automatic control circuits, 4-11 to 4-15
      - offset transformer, 4-13 to 4-15
      - synchronizing relay K102, 4-11 to 4-13
    - local control ciruits, 4-9 to 4-11
      - aided tracking tachometer, 4-10 to 4-11
      - local control signal, 4-10
      - stabilizing voltages, 4-11
    - motor field control circuits, 4-17
    - position, speed, and current-limiting circuits, 4-15 to 4-17
    - train amplifier, the, 4-3 to 4-9
      - circuit balance, 4-7
      - coupling to second stage, 4-5 to 4-6
      - function of the first stage, 4-3 to 4-5
      - second stage amplification, 4-6
      - stabilizing circuit, 4-7 to 4-9
      - thrid stage amplification, 4-7
  - electron tubes, 4-1 to 4-3
    - elements of a tube, 4-1 to 4-3
      - diode tubes, 4-1 to 4-2
      - triode tubes, 4-2 to 4-3
  - maintenance, 4-17 to 4-19
    - repair, 4-18 to 4-19
    - supervision, 4-18
  - safety, 4-19 to 4-21
    - care of shock victims, 4-20 to 4-21
    - electric shock, 4-19 to 4-20
- Amplidyne generator, 3-3 to 3-10
- Amplidyne power drives, 3-1 to 3-18
  - amplidyne generator, 3-3 to 3-10
    - additional fields, 3-8 to 3-9
      - killer generator, 3-8
      - quadrature field winding, 3-8 to 3-9
    - compensating winding, 3-6 to 3-7
    - complete picture, 3-9
    - control is used, how the, 3-7 to 3-8
    - control winding, 3-7
    - general characteristics, 3-9 to 3-10
    - load brushes, 3-6
  - drive motors, train and elevation, 3-10
  - power control circuits, 3-10 to 3-17
    - circuits, overload protection, 3-15 to 3-16
    - motor start switches, 3-12 to 3-15
    - parallax amplifier power supply circuit, 3-15
    - power supply unit, 3-16 to 3-17
- Amplidyne power drive—Continued
  - power drive, basic function of the, 3-2 to 3-3
    - automatic control, 3-2
    - gun control station, 3-3
    - local control, 3-2 to 3-3
  - safety, 3-17 to 3-18
- Amplidyne servo systems, 2-21 to 2-24
- Amplifier alignment, 9-12 to 9-13
- Amplifier, the train, 4-3 to 4-9
- Antikick action, 5-9 to 5-10
- Antioverhaul mechanism, 5-9
- Automatic control, 3-2
- Auxiliary gear pump, 5-12
- Auxiliary pumps, 5-27 to 5-28
- Auxiliary relief valve block, 5-12 to 5-15

B

- Battery alignment, 8-1 to 8-14
  - terms, basic, 8-1
  - theory of alignment, 8-1 to 8-14
    - alignment equipment, 8-4 to 8-12
      - Analog Inclination Data System (AIDS), 8-9
      - clinometers, 8-6
      - gunner's quadrant Mk 7, 8-10 to 8-12
      - levels, 8-6 to 8-9
      - optical alignment instruments, 8-9
      - tram bars, 8-9 to 8-10
      - transits and theodolites, 8-4 to 8-6
    - alignment procedures, 8-12 to 8-14
      - benchmark and tram reference readings, 8-13
      - performance of train and elevation alignment, 8-13
      - sequence of alignment, 8-12
    - alignment responsibilities, 8-4
    - definition of alignment, 8-1 to 8-4
      - reference frame, 8-2 to 8-3
- Brake, power-off, 6-29 to 6-33
- Brake valves, 5-8 to 5-9
- Brushes, load, 3-6

C

- Chemical ammunition, 11-13
- Circuit, overload protection, 3-15 to 3-16
- Circuit, parallax amplifier power supply, 3-15
- Classification codes, 1-3 to 1-4

Classified material, physical security of, 12-16 to 12-19
Classified material, securing, 12-17
Communication, effective, 1-1 to 1-2
Compensating winding, 3-6 to 3-7
Control circuits, automatic, 4-11 to 4-15
Control circuits, gun, 4-3 to 4-17
Control circuits, local, 4-9 to 4-11
Control circuits, motor field, 4-17
Control circuits, power, 3-10 to 3-17
Control is used, how the, 3-7 to 3-8
Control, local, 3-2 to 3-3
Control winding, 3-7
CT, the role of the, 2-4 to 2-5
CX rotor, turning, 2-6 to 2-7

D

Drive motors, train and elevation, 3-10
Dual-speed system, 2-11 to 2-12

E

Electric motor and speed reducer, 5-10
Electric motor (5"/38), 5-3
Electric motor (5"/54), 5-18
Electric motor (16-inch turret), 5-27
Electric shock, 4-19 to 4-20
Electrical equipment, 6-37 to 6-39
Electric-hydraulic servo systems, 2-24 to 2-25
Electron tubes, 4-1 to 4-3
Electronic servo control unit, 6-19 to 6-22
Equipment, supervision of personnel and, 11-5 to 11-6

F

Fields, additional, 3-8 to 3-9
Filters, 5-31 to 5-33
Fire control, 7-1 to 7-4
    system operability tests, 7-1 to 7-3
        daily system operability test (DSOT), 7-1 to 7-3
        interface tests, 7-3
            end-around test (EAT), 7-3
            programed operational functional appraisal (POFA), 7-3
        overall combat system operability test (OCSOT), 7-1
    test results, 7-3 to 7-4
Fluid level and pressure checks, 5-30
Forms, 12-3
Fuze chains, 10-1 to 10-3
Fuze, setting the, 10-3
Fuze-set cycles, index and, 10-19 to 10-22
Fuze-setting devices, 10-1 to 10-28
    fuze-setting equipment for the 5"/38 twin mount, 10-1 to 10-14
        fuze chains, 10-1 to 10-3
        indicator-regulator, 10-1
        Mk 9 fuze-setting indicator-regulator, 10-3 to 10-14
            indicating section, 10-5 to 10-6
            limit-stop mechanism, 10-12 to 10-14
            operating precautions, 10-14
            operating under control of the low-speed indicating TRB and follow-up head, 10-11 to 10-12
            power control synchro (TRB) and power control head, 10-6 to 10-9
            principle of operation of the power control head, 10-9 to 10-11
        setting the fuze, 10-3
    fuze-setting equipment for the 5"/54 Mk 42 mods 9 and 10 gun mounts, 10-14 to 10-23
        fuze-setter actuating mechanism and solenoid, 10-16 to 10-17
            solenoid housing, 10-16
            valve block, 10-16 to 10-17
        fuze-setter amplifier, Mk 42 gun system, 10-19
        fuze-setter assembly, 10-17 to 10-19
            fuze pot, 10-18
            fuze-setter gearing, 10-18 to 10-19
            housing, 10-17
            hydraulic motor, 10-18
            servo valve, 10-18
            synchros, 10-18
        index and fuze-set cycles, 10-17 to 10-22
        index cycle, 10-22 to 10-23
        solenoid valve and manifold, 10-14 to 10-16
            filter clogged valve block, 10-15
            fluid filters, 10-15
            main valve block and manifold, 10-15 to 10-16
            solenoid housings, 10-14 to 10-15

- Fuze-setting devices—Continued
  - fuze-setting equipment for the 5″/54 Mk 45 gun mount, 10-24 to 10-27
    - fuze-setter actuating mechanism, 10-25
    - fuze-setter amplifier, Mk 45 gun system, 10-25
    - fuze-setter assembly, 10-24 to 10-25
      - electrohydraulic servo valve, 10-25
      - fuze pot, 10-25
      - gearing, 10-24 to 10-25
      - housing, 10-24
      - hydraulic motor, 10-25
      - synchros, 10-25
    - fuze-setter indexing cycle, 10-26 to 10-27
  - safety, 10-27 to 10-28
- Fuze-setting equipment for the 5″/38 twin mount, 10-1 to 10-14
- Fuze-setting equipment for the 5″/54 Mk 42 Mods 9 and 10 gun mounts, 10-14 to 10-23
- Fuze-setting equipment for the 5″/54 Mk 45 gun mount, 10-24 to 10-27
- Fuze-setter actuating mechanism, 10-25
- Fuze-setter actuating mechanism and solenoid, 10-16 to 10-17
- Fuze-setter amplifier, Mk 42 gun system, 10-19
- Fuze-setter amplifier, Mk 45 gun system, 10-25
- Fuze-setter assembly, 10-17 to 10-19, 10-24 to 10-25
- Fuze-setter indexing cycle, 10-26 to 10-27

G

- GMG duty assignments, 1-6 to 1-7
- Gun control station, 3-3
- Gun mount control equipment, 5″/38, 6-1 to 6-16
- Gun mount control equipment, 5″/54 Mk 42 Mods 9 and 10, 6-16 to 6-33
- Gun mount control equipment, 5″/54 Mk 45, 6-33
- Gun mount power drive, 5″/38 twin, 5-2 to 5-10
- Gun mount power drives, the 5″/54 Mk 42 Mods 9 and 10, 5-10 to 5-17
- Gun mount power drive, the 5″/54 Mk 45 Mod 0, 5-17 to 5-26
- Gunner's Mate G (Guns) rating, the, 1-1 to 1-14
  - advancement, 1-10 to 1-14
    - Advancement Handbook for Petty Officers, The, 1-11 to 1-12
    - Advancement opportunities for senior petty officers, 1-12 to 1-14
      - advancement to warrant or commissioned officer, 1-12 to 1-14
      - your next step, 1-12
    - qualifying for advancement, 1-10 to 1-12
    - who will be advanced?, 1-11
  - Gunner's Mate rating, the, 1-3 to 1-7
    - assignment priorities, 1-4 to 1-6
    - classification codes, 1-3 to 1-4
      - entry series, 1-3 to 1-4
      - rating series, 1-4
      - special series, 1-4
    - GMG duty assignments, 1-6 to 1-7
      - out-of-rating assignments, 1-7
      - tour lengths, 1-7
  - personnel assignment system, 1-7 to 1-10
    - detailing, 1-9 to 1-10
      - billet variables, 1-9 to 1-10
      - external variables, 1-10
      - individual variables, 1-9
    - duty preferences, 1-8 to 1-9
    - personnel requisition system, 1-7
    - types of duty, 1-7 to 1-8
  - senior petty officer responsibilities, 1-1 to 1-3
    - effective communication, 1-1
    - stay up to date, 1-1 to 1-2
    - training, 1-2 to 1-3
      - new training techniques, 1-2
      - on-the-job training, 1-2
      - personnel qualification standards program, 1-2 to 1-3
- Gunner's Mate Rating, the, 1-3

H

- Hydraulic control equipment, 6-1 to 6-39
  - gun mount control equipment, 5″/38, 6-1 to 6-16
    - methods of control, 6-1 to 6-2
      - coarse control, 6-12 to 6-14
      - indicating section, 6-2 to 6-4
      - limit-stop operation, 6-12
      - methods of operation, 6-8 to 6-12
      - overtravel due to change in signal, 6-14

Hydraulic control equipment—Continued
  gun mount control equipment—Continued
    methods of control—Continued
      regulator control equipment, 6-4 to 6-5
      regulator electrical equipment, 6-4
      regulator valve block, 6-5 to 6-8
      synchro power failure device operation, 6-15 to 6-16
      synchronizing control device operation, 6-14
  gun mount control equipment, 5″/54 Mk 42 Mod 9 and 10, 6-16 to 6-33
    electronic servo control unit, 6-19 to 6-22
    force motor coils, 6-22 to 6-24
    limit-stop actuation (train), 6-27 to 6-29
      combined train and elevation cutout operation, 6-28 to 6-29
      train limit-stop cam, 6-28
    limit-stop mechanism, 6-24 to 6-26
      limit-stop assembly, 6-24
      limit-stop lever, 6-24 to 6-25
      override device, 6-25 to 6-26
      wobble gear, 6-24
    methods of control, 6-16
    nonpointing zone cutout system, 6-26
    power-off brake, 6-29 to 6-33
      air motor operation, 6-32 to 6-33
      power operation, 6-30 to 6-32
    receiver-regulator, 6-16 to 6-19
      A-end response linkage, 6-18 to 6-19
      B-end response gear assembly, 6-19
      base plate, 6-17
      dither transformer, 6-18
      nonpointing zone and synchro gear assembly, 6-17
      nonpointing zone valve block, 6-18
      regulator cover, 6-17
      servo valve, 6-18
  gun mount control equipment, 5″/54 Mk 45, 6-33
  receiver-regulator, 6-33 to 6-36
    automatic stroking valve, 6-36
    fine and coarse control synchros, 6-34
    limit-stop device, 6-36
      limit-stop valve, 6-36
      stabilizing linkage, 6-36
      stabilizing valve, 6-36

Hydraulic control equipment—Continued
  receiver-regulator—Continued
    parallax computer, 6-34
    stroke response gear, 6-34 to 6-36
    synchronizing valve, 6-36
    turret response gear, 6-34
  safety, 6-36 to 6-39
    electrical equipment, 6-37 to 6-39
    hydraulic equipment, 6-37
    moving equipment, 6-37
  turret, 16″3-gun, 6-33
    automatic control, 6-33
    hand control, 6-33
Hydraulic equipment, 6-37
Hydraulic fluid, 5-31
Hydraulic power drives, 5-1 to 5-36
  gun mount power drives, the 5″/54 Mk 42 Mods 9 and 10, 5-10 to 5-17
    auxiliary gear pump, 5-12
    auxiliary relief valve block, 5-12 to 5-15
      filter components, 5-14
      power-off brake control components, 5-14 to 5-15
      pressure regulation components, 5-14
    electric motor and speed reducer, 5-10
    general description, 5-10
    header tank, 5-15 to 5-16
    hydraulic transmission (CAB unit), 5-11 to 5-12
    sump, 5-16 to 5-17
    sump pump and motor, 5-17
    train servo accumulator, 5-15
  gun mount power drive, the 5″/54 Mk 45 Mod 0, 5-17 to 5-26
    electric motor (5″/54), 5-18
    general description, 5-17 to 5-18
    hydraulic transmission (CAB unit), 5-18 to 5-20
      A-end, 5-19 to 5-20
      B-end, 5-20
      valve plate, 5-20
    safety relief valve, 5-20 to 5-23
      operation of safety relief valve, 5-22
    servo and supercharge supply system, 5-23 to 5-26
      auxiliary relief valve block, 5-23
      servo accumulator, 5-25 to 5-26
      servo and supercharge pump, 5-23

Hydraulic power drives—Continued
  hydraulic terms and purpose, 5-2
  maintenance, 5-30 to 5-34
    adjustments, 5-34
    filters, 5-31 to 5-33
    fluid level and pressure checks, 5-30
    flushing and filling the unit, 5-33 to 5-34
    hydraulic fluid, 5-31
    pumps, 5-30 to 5-31
  safety, 5-34 to 5-36
  turret power drive, the 16-inch, 5-26 to 5-30
    A-end, 5-28 to 5-29
      rotating group, 5-29
      tilting box, 5-29
      valve plate, 5-28
    angle box, 5-29
      rotating group, 5-29
      valve plate, 5-29
    auxiliary pumps, 5-27 to 5-28
      supercharge pump, 5-28
      servo pump, 5-27 to 5-28
    B-end, 5-29
    electric motor (16-inch turret), 5-27
    general description, 5-26 to 5-27
    speed reducer, 5-27
    sump pump, 5-29 to 5-30
  twin gun mount power drive, 5″/38, 5-2 to 5-10
    antikick action, 5-9 to 5-10
    antioverhaul mechanism, 5-9
    brake valves, 5-8 to 5-9
    control, 5-8
    electric motor (5″/38), 5-3
    general description, 5-2 to 5-3
    hydraulic transmission, 5-4 to 5-8
      A-end, 5-4 to 5-6
      auxiliary pump cluster, 5-6 to 5-8
      B-end, 5-6
    main reduction gear, 5-3 to 5-4
Hydraulic terms and purpose, 5-2
Hydraulic transmission, 5-4 to 5-8
Hydraulic transmission (CAB unit), 5-11 to 5-12, 5-18 to 5-20

I

Indicator-regulator, 6-2 to 6-16, 10-1
Integral control, 2-16 to 2-18

L

Logs, 12-3 to 12-4

M

Magazines, designation of, 11-19 to 11-10
Magazines fittings and equipment, 11-10
Magazines, types of, 11-9
Maintenance, 5-30 to 5-34, 9-2
Maintenance, 4-17 to 4-19
  repair, 4-18 to 4-19
  supervision, 4-18
Maintenance, 13-1 to 13-16
  electrical and electronic system maintenance, 13-2 to 13-6
    electrical and electronic failure, 13-6
    electrical maintenance, 13-5 to 13-6
    interlock switches, 13-2 to 13-5
      cleaning electrical components, contacts, and switches, 13-5
      equipment-mounted interlock switches elements, 13-2 to 13-4
      solenoid-mounted interlock switch elements, 13-4 to 13-5
  hydraulic system maintenance, 13-9 to 13-10
    contamination checks, 13-9
    filtering, 13-9
    hydraulic equipment safety, 13-10
    operation under environmental changes, 13-9 to 13-10
    preventing contamination, 13-9
  mechanical maintenance, 13-6 to 13-9
    inspection during maintenance, 13-7
    mechanical safety, 13-8 to 13-9
    safety wiring, 13-7 to 13-8
    testing handling equipment, 13-8
    torque testing, 13-6 to 13-7
  maintenance programs, 13-15 to 13-16
    board of inspection and survey, 13-15
    INSURV inspections, 13-16
  maintenance publications and notices, 13-14 to 13-15
    illustrated parts breakdown (IPB), 13-15
    NAVSHIPS publications, 13-15
    SWS technical bulletins, 13-15
  maintenance skills, 13-1 to 13-2
    maintenance planning, 13-1 to 13-2
    scheduled maintenance, 13-1
    system preventive maintenance, 13-2
  storage of fluids and lubricants, 13-10 to 13-11
    flammable storage areas, 13-10 to 13-11
    inspection of storage areas, 13-10

Maintenance—Continued
  unscheduled maintenance procedures, 13-11 to 13-13
    gun barrel maintenance, 13-13 to 13-14
      gun wear, 13-13
      Mk 9 Mod 0 projectile seating distance gage (PSDG), 13-14
      star gauge, 13-13 to 13-14
    prefiring maintenance checks, 13-11 to 13-13
      firing cutout systems, 13-11 to 13-12
      limit-stop system testing, 13-12
      recoil and counterrecoil systems, 13-12 to 13-13
Maintenance checks, prefiring, 13-11 to 13-13
Maintenance data system (MDS), 12-15
Maintenance, electrical and electronic system, 13-2 to 13-6
Maintenance, electronic, 13-5 to 13-6
Maintenance, hydraulic system, 13-9 to 13-10
Maintenance, inspection during, 13-7
Maintenance, mechanical, 13-6 to 13-9
Maintenance planning, 13-1 to 13-2
Maintenance procedures, unscheduled, 13-11 to 13-14
Maintenance programs, 13-15 to 13-16
Maintenance publications and notices, 13-14 to 13-15
Maintenance, routine, 9-2
Maintenance, scheduled, 13-1
Maintenance skills, 13-1 to 13-2
Maintenance, system preventive, 13-2
Megger, 9-4 to 9-5
Missiles, surface-launched, 11-14
Mk 9 fuze-setting indicator-regulator, 10-3 to 10-14
Multimeter, 9-5 to 9-6

O

Ohmmeter, 9-3 to 9-4
Ordnance applications of control synchro systems, 2-8

P

Personnel assignment system, 1-7
Personnel requisition system, 1-7
Picture, complete, 3-9
Planned maintenance system (PMS), 12-12 to 12-16
Power drive, basic function of the, 3-2 to 3-3
Power supply unit, 3-16 to 3-17
Pumps, 5-30 to 5-31

Q

Qualifying for advancement, 1-10 to 1-11

R

Receiver-regulator, 6-16 to 6-19, 6-33 to 6-36
Repair, 4-18 to 4-19
Reports, 12-1 to 12-3

S

Safety, 4-19 to 4-21
Safety, 3-17 to 3-18, 5-34 to 5-36, 6-36 to 6-39, 9-14 to 9-16
Safety, 10-27 to 10-28
Safety relief valve, 5-20 to 5-23
Servo principles, 2-9 to 2-10
Servo systems, characteristic of, 2-12 to 2-13
Servo systems ratings, 2-25
Servo terminology, 2-10 to 2-11
Servomechanisms and servo systems, 2-9 to 2-28
Shipboard gunnery logs and records, 12-3 to 12-8
Shipboard tests and test equipment, 9-6 to 9-14
Ship's armament inventory list (SAIL), 12-7 to 12-8
Solenoid valve and manifold, 10-14 to 10-16
Sump, 5-16 to 5-17
Sump pump, 5-29 to 5-30
Sump pump and motor, 5-17
Switches, motor start, 3-12 to 3-15
Synchro capacitors, 2-8 to 2-9
Synchro gearing, 2-18 to 2-21
Synchro systems, errors in control, 2-7 to 2-8
Synchro transmitter, operation with a, 2-5 to 2-6
Synchros, 2-1
3-M Systems, 12-12 to 12-16
Synchros and servo systems, 2-1 to 2-28
  control synchro systems, 2-4 to 2-9
    errors in control synchro systems, 2-7 to 2-8
      electrical error, 2-7
      errors of control transformers, 2-7 to 2-8
      use of torque and control units in same system, 2-8

- Synchros and servo systems—Continued
  - control synchro systems—Continued
    - operation with a synchro transmitter, 2-5 to 2-6
    - ordnance applications of control synchro systems, 2-8
    - role of the CT, the, 2-4 to 2-5
    - synchro capacitors, 2-8 to 2-9
    - turning CX rotor, 2-6 to 2-7
  - servomechanisms and servo systems, 2-9 to 2-28
    - amplidyne servo systems, 2-21 to 2-24
    - characteristics of servo systems, 2-12 to 2-13
      - oscillating, 2-13
      - overshooting, 2-13 to 2-14
      - reducing overshooting, 2-14
    - dual-speed system, 2-11 to 2-12
    - electric-hydraulic servo systems, 2-24 to 2-25
    - integral control, 2-16 to 2-18
    - maintenance, 2-25 to 2-28
      - established installations, 2-26 to 2-28
      - installations, new, 2-26
      - troubleshooting synchro systems, 2-26
      - zeroing synchros, 2-25 to 2-26
    - servo principles, 2-9 to 2-10
    - servo system ratings, 2-25
    - servo terminology, 2-10 to 2-11
    - synchro gearing, 2-18 to 2-21
      - optical servo system, 2-20
      - position indicator, 2-20
      - servo system components, 2-20 to 2-21
    - velocity system, 2-14 to 2-16
  - synchros, 2-1
  - torque synchro systems, 2-1 to 2-4
    - factors that affect the accuracy of a torque synchro system, 2-2 to 2-4
      - simple torque systems, 2-3
      - torque systems involving a number of receivers, 2-3
      - transmitter with many receivers, one, 2-3 to 2-4
    - ordnance applications of torque synchro systems, 2-4
    - torque synchros systems containing differential units, 2-2
    - transmitter and receiver, 2-1 to 2-2
- Synchros, fine and coarse control, 6-34
- Synchros systems, control, 2-4 to 2-9

T

- Test equipment, 9-1 to 9-16
  - maintenance, 9-2
    - corrective maintenance, 9-2
    - routine maintenance, 9-2
  - safety, 9-14 to 9-16
  - shipboard tests and test equipment, 9-6 to 9-14
    - amplifier alignment, 9-12 to 9-13
    - comparing performance data, 9-6 to 9-7
    - dummy fuze test gage, 9-14
    - gun battery test equipment, 9-12
    - hydraulic test kit, 9-13 to 9-1-4
    - reading test traces, 9-13
    - test instrumentation, 9-9 to 9-12
      - error recorder (oscillograph), 9-9 to 9-10
      - external (dummy) director, 9-10 to 9-12
    - testing problems, 9-7 to 9-8
    - types of train and elevation traces, 9-8
      - B-end error trace, 9-8
      - B-end position trace, 9-8
      - B-end velocity trace, 9-8
  - test instruments, 9-2 to 9-6
    - megger, 9-4 to 9-5
    - multimeter, 9-5 to 9-6
    - ohmmeter, 9-3 to 9-4
    - TV-7D/U tube tester, 9-6
    - voltmeter, 9-3
- Test equipment, gun battery, 9-12
- Test gage, dummy fuze, 9-14
- Test instrumentation, 9-9 to 9-12
- Test instruments, 9-2 to 9-6
- Test (OCSOT), overall combat system operability, 7-1
- Test (DSOT), daily system operability, 7-1 to 7-3
- Test results, 7-3 to 7-4
- Tests, interface, 7-3
- Tests, system operability, 7-1 to 7-3
- Torque synchro system, factors that affect the accuracy of a, 2-2 to 2-4
- Torque synchro systems, 2-1 to 2-4
- Torque synchro systems containing differential units, 2-2
- Training, 1-2 to 1-3
- Transmitter and receiver, 2-1 to 2-2
- Tube, elements of a, 4-1 to 4-3
- Turret power drive, the 16-inch, 5-26 to 5-30
- Turret response gear, 6-34
- Turret, 16″ 3-gun, 6-33
- TV-7D/U tube tester, 9-6

V

- Velocity system, 2-14 to 2-16
- Voltmeter, 9-3

☆ U.S. GOVERNMENT PRINTING OFFICE; 1990-731-068/20029

UNIVERSITY OF ILLINOIS-URBANA
3 0112 105163734